





THE
YOUNG GENTLEMAN AND LADY'S
PHILOSOPHY,
IN A
CONTINUED SURVEY
OF THE
WORKS OF NATURE AND ART;
By Way of DIALOGUE.

VOLUME II.

CONTAINING,

- I. The Use of the *Celestial* and *Terrestrial* GLOBES.
- II. The PHILOSOPHY of LIGHT and COLOURS, and
the Use of all Sorts of *Optical* INSTRUMENTS.
- III. The PHILOSOPHY of SOUNDS, MUSIC, and the
Organization of the EAR.

Illustrated by Nineteen COPPER-PLATES.

THE THIRD EDITION CORRECTED.

By BENJAMIN MARTIN.

L O N D O N,

Printed for W. OWEN, No. 11, near *Temple-Bar*; and
by the AUTHOR, at his House in *Fleet-Street*.

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THE
YOUNG DEPARTMENT
PHILOSOPHY

IN A
CONTINUED SERIES
OF THE
WORKS OF NATURE AND ART
BY HENRY DUNN

VOLUME II



THIRD EDITION
BY HENRY DUNN

LONDON

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THE
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PART IV.
CONTAINING
The Description and Use of the CELESTIAL
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and PLANISPHERES.

DIALOGUE I.
*The Description of the CELESTIAL GLOBE, and its
FURNITURE.*

Cleonicus.
AS our last Conversation finished our Speculation on the Atmosphere, we are brought, by our proposed Method, to a View of the artificial Globes.—And that Nothing may be wanting to give you a perfect Idea of the most wonderful and obvious Parts of Nature, I mean, the Frame and Constitutions of the Heavens and the Earth, and all their sensible Motions and Phenomena; I have provided a Pair of GLOBES for that Purpose, twenty-eight Inches Diameter.—And here they are.—This is called the *Celestial Globe*, and that the *Terrestrial*.—
Euphras. I am infinitely obliged to you, *Cleonicus*, for the Care and Trouble you have on my Account.

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They are very beautiful Things indeed ! And I question not but they are of equal Use. — As we cannot consider the Uses of both at once, pray which do we begin with ?

Cleon. The *Celestial Globe*, my *Euphrosyne*, for that remains to finish our practical View of the Heavens. — We at first contemplated the Theory of the *Mundane System*—then we took an *actual Survey* of the *several Bodies* which composed it, and their *Motions*, by the *Telescope* ; —after this, we assayed the *Doctrine of the Sphere* ;—and then considered, under a more immediate View, the *various Motions and Affections of the Heavenly Bodies*, in themselves, and in regard of each other, in the *Orrery* ; —and now it remains, that we contemplate the same Thing in regard to the Earth (or its Inhabitants) only, which is to be done by the *Celestial Globe* ; whose Superficies represents the *constellated Canopy of the Heavens*, and its Rotation about its Axis, the *apparent diurnal Motions of the Sun, Moon, and Stars*. — And hence this Globe has the Name *Celestial*.

Euphros. I must wait till you are more particular in the Uses of this fine Instrument ;—at present I observe most of the Circles of the Sphere upon it, —and several Figures of *Men, Women, Horses, Dogs, Serpents, Fishes, Crowns, &c.* painted thereon, which, I suppose, are all significant, when understood. —

Cleon. True, Sister ; here are all the Circles of the Sphere ; and it is little different from the Sphere, in any Thing more than having a continued Surface, and the *Constellations* painted thereon.

Euphros. Yes, here is this broad Horizon, with several Circles upon it—pray, what Circles are they ?

Cleon. There are five Circles on the Horizon, *viz.*
 (1) The inmost, or that next the Globe, is the *Circle of Amplitudes or Azimuths*, and divided each Way from *East* and *West*, towards *North* and *South*, into 90 Degrees.
 (2) The Circle containing the 32 *Points of the Compass*.
 (3) The *Calendar of Months and Days*, according to the *New Style*. (4) The *Zodiac*, with the Signs and Degrees of the *Ecliptic*, adapted thereto. (5) The *Calendar for the Old Style* adjusted to the *Ecliptic* ; —the Uses of all these you will see more particularly hereafter. —

Euphros.

Euphros. Very good, *Cleonicus*: and as to the other Circles on its Surface; the *Equinoctial*, the *Ecliptic*, the *Tropics*, and *Polar Circles*, I shall trouble you with no Questions concerning them, having had a perfect Knowledge of them from the Sphere.—But these other Circles, which run athwart and cross the Globe, and cut each other, what are they?

Cleon. They are of two Sorts, viz. *Circles of Longitude*, which pass through the Poles of the *Ecliptic*, and therefore at right Angles to the *Ecliptic*; of these there are 12, which terminate the 12 Signs; and divide the Surface of the Globe into 12 equal Parts; these equal Parts in the Heavens were called the *Celestial Houses* by *Ptolemy* and other ancient Astrologers. The other Sort are called *Circles of Declination*; these all pass through the Poles of the World, and cut the *Equinoctial* at right Angles at every 30th Degree; they are also 12 in Number, and divide the Surface of the Globe into other 12 equal Parts, which were in the Heavens accounted the 12 *Celestial Houses* by that Astrologer, but other Astrologers in after Times invented other Divisions of the Heavens for their Houses, as their Fancies and Superstition suggested.

Euphros. How came they to call these Divisions Houses? And what did they intend thereby?

Cleon. In ancient Times, when the World was very ignorant, *Superstition* was all the Fashion; and *Imposture* a venerable Thing. Then was the Time for the Men of Front; they invented Schemes and Figures of the Heavens to amuse and surprise the Vulgar, making them believe the Stars were the very Ministers of Fate, having a governing Influence over all Things below. Hear how solemnly *Manilius* talks on this Subject.—

When Nature order'd this vast Frame to rise,
Nature, the Guardian of these Mysteries,
And scatter'd lucid Bodies o'er the Skies;
When she the Concave, whence directly fall
Streight Lines of Influence round the solid Ball,
Had fill'd with Stars; and made Earth, Water, Air,
And Fire, each other mutually repair;
That Concord might these differing Parts controul,
And Leagues of mutual Aid support the Whole;

*That nothing which the Skies embrace might be
From Heaven's supreme Command and Guidance free,
Long time she thought, then hung his Fates on Stars,
Those Stars, which plac'd i'th' Heart of Heaven display
The brightest Beams, and share the greatest Sway;
Which keep a constant Course, and now restrain
The Planets Pow'r, now yield to them again:
Thus sometimes ruling, sometimes rul'd, create*

The strange and various Intercourse of Fate. Lib. III.

And every Thing of this Kind was sacred which they said; yea, so credulous were the unthinking Vulgar, that Nothing could be advanced too monstrous and ridiculous for them not to believe. Thus a modern *French Astrologer* is gibed by *Hudibras*—

*Cardan believ'd great States depend
Upon the Tip o' th' Bear's Tail's End;
That as she wisk'd it tow'rd the Sun,
Straw'd mighty Empires up and down.*

And as to the Imposture and Nonsense of ancient *Sooth-sayers*, see it merrily ridiculed in his 3d Canto of Part II. But we make too long a Digression, were it not that so impious and scandalous a Pretension cannot be too much ridiculed and exploded.—

Euphras. I do not understand Astrology, and if its Pretensions are such as you insinuate, it must indeed be a vain and presumptuous Thing, and borders very nearly on Blasphemy.—But to the Subject of the Globe; what are those various Figures of *Men, Beasts, &c.* on the Surface, and why are they painted there?

Cleon. They are all imaginary Beings, and have their Existence no where but on the Surface of the artificial Globe: they were contrived for the sake of *Memory* and *Comprehension*; and are of very great Antiquity. For the Stars appearing, as it were, confusedly disseminated or strewed over the vast concave Expanse of Heaven, could not without some Artifice be well comprehended by the Mind, or remembered with respect to *Magnitude* and *Situation*. To have given Names to each Star, would have been too great a Burthen to the Memory: and to reduce them all to Catalogues, and point them out by their Places, was a Work of Ages, as I have shewed you before. The only Expedient therefore to facilitate the
Knowledge

Knowledge of the Stars, was to consider and distribute them into various Companies, or Collections, and the better to fix the Idea of these in the Mind, they invested them with the Figures and Characters drawn from Men, Beasts, and Things, as would best fit and suit with each : And to these they properly gave the Name of *Constellations*, or *Asterisms*; and painted them on their Globes and Machines. Concerning which, thus *Manilius*.

Now Constellations, *Muse*, and Signs rehearse,
In order, let them sparkle in thy Verse;
Those which obliquely bound the burning Zone,
And bear the Summer and the Winter Sun,
Those first: Then those which roll a different Way
From West: Nor Heaven's diurnal Round obey;
Which Nights serene disclose, and which create
The steady Rules, and fix the Laws of Fate.

Book I.

Euphros. How many Constellations are there in all?

Cleon. They are reckoned 56 in Number; viz. 12 in the Zodiac; 29 on the North of the Zodiac; and 25 on the South Side thereof.

Euphros. What are the Names of those in the Zodiac?

Cleon. The very same with the Names of the Signs; as *Aries*, *Taurus*, *Gemini*, &c. which you know very well already.

Euphros. I do, without a Repetition;—but what Names do those bear in the northern Hemisphere?

Cleon. The 29 Northern Constellations, are

1. *Ursa Minor*, or the lesser Bear.
2. *Ursa Major*, or the greater Bear.
3. *Draco*, or the Dragon.
4. *Cepheus*.
5. *Cygnus*, or the Swan.
6. *Perseus*.
7. *Andromeda*.
8. *Auriga*, or the Waggoner.
9. *Coma Berenicens*, or *Berenice's Hair*.
10. *Bootes*.
11. *Corona Septentrionalis*, or *Northern Crown*.
12. *Hercules*.
13. *Lyra*, or the Harp.
14. *Aquila cum Antinous*; the Eagle with *Antinous*.

15. *Delphinus*, or the *Dolphin*.
16. *Equuleus*.
17. *Pegasus*; the *Winged Horse*.
18. *Triangulus*; the *Triangle*.
19. *Cassiopeia*.
20. *Serpentarius*, or *Ophiuchus*.
21. *Lacerta*; the *Lizard*.
22. *Serpens Ophiuchi*; the *Serpent of Ophiuchus*.
23. *Lynx*.
24. *Sagitta*; the *Arrow*.
25. *Orion cum Scuto*; *Orion with a Shield*.
26. *Camelopardus*.
27. *Anser cum Vulpeculâ*; the *Goose with the Fox*.
28. *Leo Minor*; the *lesser Lion*.
29. *Canes Venatici*; the *Courting Dogs*.

Euphros. I observe them all in the Order you have named them; and more than these I see which you have not mentioned—as that Star in the Heart there, &c.

Cleon. Very good, Sister; you mean *Cor Caroli*, or *Charles's Heart*, which is a new Star, unknown to the ancient Astronomers, and therefore not contained in any of their Constellations. Besides this, there are divers other Stars of less Note, not reducible to any Constellation, which are therefore by Astronomers called *extra-constellated Stars*.

Euphros. Well, now for the Names of the Constellations on the South Part of the Globe, *Cleonicus*; of which I think you say there are about 25.—

Cleon. Yes; That is the Number by some, by others they are reckoned 28. Their Names are as follow,

1. *Balenus*, or *Cetus*; the *Whale*.
2. *Canis Minor*; the *lesser Dog*.
3. *Centaurus cum Lupo*; the *Centaur with the Wolf*.
4. *Corona Australis*; the *Southern Crown*.
5. *Crater*; the *Water-pot*.
6. *Eridanus*; the *River Po*.
7. *Monoceros*, or *Unicorn*.
8. *Canis Major*; the *Greater Dog*.
9. *Argo*; the *Ship*.
10. *Ara cum Thuribulo*; the *Altar and Censer*.
11. *Grus*, or the *Crane*.
12. *Lepus*, or the *Hare*.

13. *Pavo*;

13. *Pavo*; the *Peacock*.
14. *Phœnix*.
15. *Sextans*; the *Sextant*.
16. *Triangulum*; the *Triangle*.
17. *Toucan*, or *American Goose*.
18. *Apous*; the *Indian Bird*.
19. *Columba Noachi*; *Noah's Dove*.
20. *Musca*; the *Fly*.
21. *Robor Caroli*.
22. *Hydrus*, a *Serpent*.
23. *Piscis volans*; the *Flying Fish*.
24. *Chameleon*.
25. *Xiphias*; the *Sword-fish*.
26. *Crux*; the *Cross*.
27. *Indus*; the *Indian*.
28. *Corvus*; the *Raven*.

These Constellations, you see, are all distinctly painted on the Celestial Globe, with here and there some extra-constellated Stars, as I observed to you before.

Euphros. They are all so plain, that they who run may read them. Pray, *Cleonicus*, are not these Constellations of very great Antiquity?

Cleon. Yes, my *Euphrosyne*, for some of them are mentioned in the Writings of the most ancient Historian in the World.—

Euphros. I suppose you mean *Job*; for in that Book I have read of *Arcturus*, *Orion*, the *Pleiades*, &c.

Cleon. Yes, that is the History I mean. It is supposed by learned Men, that *Job* lived in *Arabia*, and wrote his History before the Time of *Moses*, and therefore is the most ancient of any extant; and since he speaks of the Constellations so particularly, and by the Names they now bear, it must follow, that the Method of computing the Stars, and distributing them into Companies or Constellations, is of the greatest Antiquity of any Thing in the liberal Sciences.—Thus *Job* in the xxxviiiith Chap. makes Mention of the *Pleiades*, or *Seven Stars*,—of *Mazzaroth*, or the *Zodiac* of the 12 *Signs*,—of the Constellations *Orion* and *Arcturus*, and the *Ordinances* of Heaven, which he calls the *Chambers of the South*, in Chap. ix. and undoubtedly means the Southern Constellations, or Divisions of the Heavens.—

Euphros. I observe, as I look over the Constellations on the Globe, that some Stars are very large, and others very small; pray, how many different Sorts or Sizes of Stars do you reckon?

Cleon. Astronomers reckon *Seven Degrees of Magnitude* in the Stars,—you see here an Example of them all, which Mr. SENEX has fixed on the Globe in this Row of Stars, gradually diminishing from the greatest to the least.

Euphros. The largest, I suppose, you call the *first Magnitude*, do you not?

Cleon. Yes, my *Euphrosyne*, the largest Stars are those of the first Magnitude which you see consist (on the Globe) of six large, and six small radiant Points or Beams; by which, as well as by their Magnitude, they are very easily distinguished all over the Globe; as the Stars in the Firmament, which they represent, are larger, more scintillant, and brilliant above the rest.

Euphros. Yes, I easily distinguish them from the rest on the Globe; but I observe they are but few in Number; and most of them have Names I see affixed to them.

Cleon. They are indeed but few in Number; I remember Mr. *Flamsteed*, in his *Historia Cœlestis*, makes but 15 in both Hemispheres,—but on this Celestial Globe of Mr. *Senex's*, you tell about 16 Stars of the first Magnitude. These Stars are, as you observe, signalized with proper Names, as *Aldebaran*, *Regulus*, *Arcturus*, *Deneb*, *Alengur*, *Rigel*, *Sirius*, *Antares*, *Fomabaunt*, &c.

Euphros. As to the Stars of the second Magnitude, I observe in the Sample, they have six large single Beams, but somewhat less than the other.

Cleon. Yes; and you observe too, they are more numerous, and most of them without Names.—Stars of the third Magnitude are still more numerous, and nameless,—of the fourth Magnitude their Number increases,—and of the fifth and sixth Magnitude, they increase very much;—but of the 7th they are not so many.—The Number of the Stars of every Magnitude in each Constellation, are numbered in *Flamsteed's Historia Cœlestis*; which I have transcribed in this Table, to give you a more perfect Idea of them.

	Num	Magnitudes.						
		1	2	3	4	5	6	7
In the Zodiac—	943	7	11	43	94	169	445	174
In the N. Hemisph.	1511	4	23	93	227	356	695	113
In the S. Hemisph.	547	4	20	56	136	145	176	10
Sum of all the Stars	3001	15	54	192	457	670	1316	297

Euphros. The Stars of the 6th and 7th Class, I imagine, we must have good Eyes to discern.

Cleon. They are not discernible by the best Eyes, but with the Telescope only; and are therefore called *Telescopic Stars*, as I have before hinted.—Yea, not one Eye in fifty can see Stars of the 5th Magnitude distinctly; and they must be tolerable good Eyes to distinguish and enumerate Stars of the 4th Order.

Euphros. Well, I think we have talked of the Magnitude of the Stars, till the Stars of every Magnitude shine very bright.—This is a glorious Star-light Night, but very cold.—

Cleon. It is always observable, that the colder the Night, the clearer the Stars shine, if there be no Clouds. I cannot help recollecting some choice Reflections on the Stars, a Gentleman made, as he observed them one Night in a Journey from *Patapsko* to *Anapolis*, and which may serve to conclude our present Speculation.

*Now deep'ning Shades confess th' Approach of Night,
Imperfect Images elude the Sight:*

*From earthly Objects I remove mine Eye,
And view with Look erect the vaulted Sky;
Where dimly shining now the Stars appear,
At first thin-seatt'ring thro' the misty Air;
Till Night confirm'd, her jetty Throne ascends,
On her the Moon in clouded State attends,
But soon unveil'd her lovely Face is seen,
And Stars unnumber'd wait around their Queen;
Rang'd by their Maker's Hand in just Array,
They march majestic thro' th' ethereal Way.*

*Are these bright Luminaries hung on high
Only to please with twinkling Rays our Eye?*

Or

*Or may we rather count each Star a Sun,
Round which full peopled Worlds their Courses run?
Orb above Orb harmoniously they steer
Their various Voyages thro' Seas of Air.*

DIALOGUE II.

Of the Twelve CONSTELLATIONS of the ZODIAC, with their Fabulous HISTORY.

Euphrosyne.

I Think, *Cleonicus*, you intimated last Night, that we should next take a more particular Survey of the Constellations; and of the Origin, History, &c. of each of them.

Cleon. Yes, my *Euphrosyne*; and To-night we'll begin with the *Twelve Constellations of the Zodiac*; for they offer themselves first, as being the most considerable and noted of all in the Heavens. And here we shall imitate the antient poetical Astronomer *Manilius*; who, being to give an Account of the Constellations, first rehearses them in the following Lines.——

*First Aries, glorious in his golden Wool,
Looks back, and wonders at the mighty Bull,
Whose Back-parts first appear: He bending lies
With threat'ning Head, and calls the Twins to rise;
They clasp for Fear, and mutually embrace;
And next the Twins with an unsteady Pace
Bright Cancer rolls: Then Leo shakes his Mane,
And following Virgo calms his Rage again:
Then Day and Night are weigh'd in Libra's Scales,
Equal a-while, at last the Night prevails,
And longer grown, the heavier Scale inclines,
And draws bright Scorpio from the Winter Signs:
Him Centaur follows with an aiming Eye,
His Bow full drawn and ready to let fly:
Next narrow Horns the twisted Caper shows,
And from Aquarius' Urn a Flood o'erflows.
Near their low'd Waves cold Pisces takes their Seat,
With Aries join, and make the Round compleat.*

Lib. I.

Euphros. Well, 'tis very pretty, to see, as you turn the Globe, how the Order, Situation, Posture, and Attitudes of the Constellations answer to the poetical Description.

——— But to be more particular, and begin with *Aries*, how came this Constellation by that Name and Form?

Cleon. Because, as 'tis supposed, the most ancient *Chaldean* Astronomers observing the Sun to enter this Sign, at a Time when the Fields and Hills were most remarkably replenished and overspread with Flocks, vastly encreased with the new Produce of Lambs, which (as the pastoral Life was then most considerable) they esteemed the most profitable Part of the New-year's Product; to signalize this Season, therefore, they thought fit to call this Sign, or Constellation, by the Name of the Principal of the Flock, *Aries*, or the *Ram*. At this Season *Virgil* observes——

——— *An Hundred Lambs*

Attend with bleating Cries their milky Dams.

And in another Place, speaking of the various Products of the Spring, he says,

With milder Beams the Sun securely shines,

Fat are the Lambs, and luscious are the Wines.

Georg. I.

Euphros. But though this seems very natural; yet, if I remember right, the Poets give a different Account of this Matter.

Cleon. Yes, they do so; 'tis this *Ram* and his *Golden Fleece*, of which the Poets tell us so many Stories and Fables; the Grounds of all which are thus fabulated.——

Athamas, King of *Thebes*, had, by his Wife *Nephele*, a Son named *Phrixus*, and a Daughter named *Helle*; he afterwards married another Wife, *Ino* by Name, who fell in Love with *Phrixus*; but, neglected by him, she had an extreme Aversion to him; and there happening a Dearth of Corn, she persuaded *Athamas*, that it could not be remedied 'till *Phrixus* and *Helle* were sacrificed: But as they stood at the Altar, *Nephele*, (i. e. a Cloud) took them away, and gave them a golden *Ram* that she had received from *Mercury*. On this *Ram* they fled through the Air from *Thebes*, and in their Flight *Helle* fell off into the Sea, which from thence was called *Hellepontus*. *Phrixus* arrived at *Brixada*, where, laying himself down

to

to rest, the Barbarians were coming to kill him; but the Ram awaked him, and gave him Notice with a human Voice, and then carried him to *Colchis*, where he was kindly received by *Æta* the King, who sacrificed the Ram to *Jupiter*, and hung up his Golden Fleece in the Grove of *Mars*; there it was kept by Bulls, which had brazen Feet and breathed Fire, and also by a great Dragon: The Ram was afterwards said to be taken up into the Skies, and made the Constellation we are now speaking of.

Euphros. In some such Manner too, I suppose, you deduce the Origin of *Taurus*, or the Bull, which is the next Constellation.

Cleon. You guess right; for as *Calves* were the next considerable Product of the Spring, which were now (when the Sun entered this Constellation) full-grown and fat, and led out from the Stalls to the Fields, the Altars, or the Butchers; so the pristine Astronomers and Herdsmen denoted this Season, by attributing the Name of the Bull to that Sign the Sun then possessed. And *Virgil*, by reason of a Star in the Tip of each Horn, takes occasion to call them *Golden Horns*, in the following Verses.

*When with his Golden Horns in full Career,
The Bull beats down the Barriers of the Year.*

George I.

Euphros. I suppose the Poets have a great deal to say of this fabulous Bull likewise?

Cleon. A great deal; and very merry too, for the most Part; the Story is of *Jupiter's* carrying away *Europa*, the Daughter of *Agenor*, King of *Phœnicia*, in the Form of a White Bull, into the Isle of *Crete*, where he discovered to her his Divinity, and placed the Bull among the Stars. *Ovid* relates the Circumstances of this Story very poetically thus:

*The Ruler of the Skies; the thund'ring God,
That shakes the World's Foundations with a Nod,
Among a Herd of lowing Heifers ran,
Frisk'd in a Bull, and bellow'd o'er the Plain.
Large Rolls of Fat about his Shoulders clung;
And from his Neck the double Dewlap hung.
His Skin was whiter than the new-fall'n Snow;
Small were his Horns, and harmless was his Brow:*

No shining Terrors sparkled in his Sight,
 But his Eyes languish'd with a gentle Light;
 His ev'ry Look was peaceful, and express'd
 The Softness of the Lover in the Beast.
 Agenor's royal Daughter, as she play'd
 Among the Fields, the Milk-white Bull survey'd,
 And view'd his spotless Body with Delight,
 And at a Distance kept him in her Sight.
 At length she pluck'd the rising Flow'rs, and fed
 The gentle Beast, and fondly strok'd his Head.
 He stood well-pleas'd to touch the charming Fair,
 But hardly could confine his Pleasure there.
 And now he wantons o'er the neighb'ring Strand,
 Now rolls his Body on the yellow Sand,
 And finding all the Virgin's Fear decay'd,
 Comes tossing forward to the royal Maid;
 Gives her his Breast to stroke, and downward turns
 His grisly Brow, and gently stoops his Horns.
 In flow'ry Wreaths the Royal Virgin drest,
 His bending Horns, and kindly clapp'd his Breast.
 Till now grown wanton, and devoid of Fear,
 Not knowing that she press'd the Thunderer,
 She fix'd herself upon his Back, and rode
 O'er Fields and Meadows, seated on the God.
 He gently march'd along, and, by Degrees,
 Left the dry Meadow, and approach'd the Seas,
 Where now he dips his Hoofs, and wets his Thighs;
 Now plunges in, and carries off the Prizes.
 The frighted Nymph looks backward on the Shore,
 And hears the tumbling Billows round her roar.
 But still she holds him fast, with one Hand horn
 Upon his Back, while 't'other grasps a Horn.
 The Train of ruffling Garments flies behind,
 Swells in the Air, and hovers in the Wind.
 Thro' Storms and Tempests he the Virgin bore,
 And lands her safe on the Dictean Shore;
 Where now in his divinest Form array'd,
 In his true Shape he captivates the Maid;
 Who gazes on him, and with wond'ring Eyes,
 Beholds the new, majestic Figure rise;
 Views his bright Features, and his native Light,
 And all the God discover'd to her Sight.

Metam. II.

Euphros. This *Bull* makes a very considerable Figure in Poetry, as well as Astronomy, I find.—But, pray, *Cleonicus*, what Origin do you give to the *Twins*, or *Gemini*?

Cleon. These owe their Original to the same Cause, in all Probability, with the two foregoing; for at this Time, (*viz.* about *May*, when the Sun enters this Sign) the Young of *Goats* were in their Maturity and Perfection; and were oftener than any other Beasts, brought forth by *Pairs*, or *Twins*; which the Goat-herds (in antient Times, being very considerable) denoted, by giving the Denomination of *Gemini* to the Sign.—

Euphros. Very good;—but what do the Poets say of this Sign *Gemini*?

Cleon. They tell us a Story of *Castor* and *Pollux*, two Sons of *Leda*; the latter by *Jupiter*, and was therefore immortal; the former by her Husband *Tyndarus*, and therefore mortal.—When *Jason* undertook the Expedition for the *Golden Fleece*, among other Heroes were *Castor* and *Pollux*; who behaved themselves very valiantly during the whole Voyage. In a Storm which happened, two strange Fires appeared playing about the Heads of *Castor* and *Pollux*, and soon after a Calm ensued, which made it thought there was somewhat divine in those Youths. It happened afterwards, that *Castor*, being mortal, was killed, and *Pollux* begged of *Jupiter* to make him immortal, which not being possible, he only obtained, that his Brother should share half his own Immortality, so that each Day they alternately lived, the One in Heaven the Other in Hell.—They were at last placed among the Stars, and made the Constellation *Gemini*, which you see on the Globe, denoted by the two Youths, with each a bright Star in his Head, and their Names *Castor* and *Pollux* to distinguish them.

Euphros. That the first Astronomers should give the Names of the *Ram*, the *Bull*, and the *Twins*, to these Constellations, you have given a sufficient Reason; but what should induce them to call the next Constellation in the Zodiac, by the Name of *Cancer*, or the *Crab*?

Cleon. You'll observe a good Deal of Propriety, even in this, if you consider, that the first Observers took Notice of the Sun's gradual Ascent above the Equinoctial

noctial to a certain Height or Meridian Altitude, from which it afterwards declined again, and descended as gradually; and then, by what Means could they more pertinently commemorate so notable an Observation, than by the *retrograde, or side-long Motion of a Crab?* And the Poets afterward, to make good their Part, tell us, that this is the *Crab* which *Juno* sent to bite and molest *Hercules*, while he was destroying the *Lernaean Hydra*, for which, when *Hercules* had killed the vexatious Animal, *Juno* placed him among the Stars.

Euphros. But how came the *Lion*, a Creature in all Respects so different from a *Crab*, to succeed immediately the *Crab*?

Cleon. As among Animals the *Lion* is the most powerful, fierce, and strong; so among the Months of the Year, that Season in which the Sun occupied this Sign, the Sun's Heat and Effects were more fierce and violent than in any other, *i. e.* about the latter End of *July*, and the Beginning of *August*; and from this Similarity, the Constellation is supposed to have had its Name by the first Observers of Time.

Euphros. This seems probable enough; and I question not but it furnished the Poets with an ample Theme for Invention.—

Cleon. It did so; for they tell us, that this is that *Nemæan Lion*, which *Juno* procured from the *Moon*, and sent against *Hercules* to kill him; but *Hercules* tore him to Pieces with his Nails, and made him a Shield and Breast-plate with his Skin. This made *Juno* hate him still more, and on the *Lion* bestowed that celestial Dignity he has ever since enjoyed.

Euphros. Well, *Cleonicus*, I perceive the Astronomers have paid a very early Regard to the Ladies, by the Compliment of placing *Virgo*, or a *Virgin*, among the Stars; pray, what was the Occasion thereof? And whence those Wings, and that Wheat-sheaf in her Hand?

Cleon. About the Time the Sun entered this Sign, the Harvest was pretty well over; and now the young Damsels appeared and spread themselves over the Fields, gleaning up the Ears of Corn. And as they made this the most agreeable Scene of rural Life, the Astronomers did

did them the Compliment of a Constellation of their own Sex, and gave them a Handful of Wheat to shew the Occasion. They also depicted her with Wings, to shew, the Harvest had, as it were, taken its Flight, and bid them farewell 'till the next Year.

Euphras. And pray, what have the Poets to say on this Occasion?

Cleon. Enough, you may be sure; they tell us, she was the Daughter of *Jupiter* and *Themis*, and the Princess of Justice, by Name *Astræa*; they feign, that in the Golden Age she descended from Heaven to the Earth, and being offended at last by the Wickedness of Mankind, she returned to Heaven again, after all the other Gods who went before her, where she obtained the Dignity of a Constellation, as described in the following Distich:

*All Duty dies, and wearied Justice flies
From bloody Earth at last, and mounts the Skies.*

And *Virgil* thus:——

*Justice last took her Flight from hence, and here
The Prince of her departing Steps appear.*

Dry. Georg. II.

Euphras. As to *Libra*, you have already hinted the Reason of the Name, from the Equality of Days and Nights; but I want to know what is said of this in fabulous History.

Cleon. When Justice fled from Earth to Heaven, 'tis natural to think, she carried her Scales with her, which might be made this Constellation; and I wonder to find the Poets and Mythologists silent in this Particular. However, it is supposed, that the exceeding Usefulness of the Balance, when first invented, excited Men to commemorate the same, by placing them among the Stars. And indeed what Invention could deserve it more, than that which is the Test and Standard of Justice among Mankind? These are the celestial Scales, in which *Jove* is feigned by *Homer*, to weigh out the Fate of Mortals, and in particular, that of *Hector*, in the following Lines.

*Jove lifts the golden Balances, that show
The Fates of mortal Men, and Things below;
Here each contending Hero's Lot he tries,
And weighs, with equal Hand, their Destinies.*

Low

*Low sinks the Scale, surcharg'd with Hector's Fate;
Heavy with Death it sinks, and Hell receives the Weight.
And of this Balance too, Virgil speaks in the following
Lines:*

*But when Astrea's Balance, hung on high,
Betwixt the Nights and Days divides the Sky;
Then yoke your Oxen, sow your Winter Grain,
'Till cold December comes with driving Rain. Geor. I.
Euphras. There are doubtless many Things of less
Merit, advanced to the Stars; else, pray, how came a
Scorpion there? Who would have thought to have found
such a terrible, such a noxious Animal in the Heavens?*

*Cleon. When you consider, that during the Season the
Sun is in this Sign, the Weather is generally very bad,
and all Kinds of Diseases now begin to invade and infect
Mankind; as Colds, Agues, Astmas, Fevers, &c. as also
that this is the Introduction to the cold and comfortless,
the dreary and deadly Season of Winter; I say, when
this is considered, you cannot think it strange, that the
first Observers gave this Sign the Name of Scorpio, being
so apt an Emblem of the Season—The Poets tell us, this
was the Scorpion which slew Orion for his Arrógance and
impudent Design on Diana.*

*Euphras. I think I remember a Passage in Ovid, where
it is said, that Scorpio fills the Space of two whole Signs;
how is that to be understood, Cleonicus?*

*Cleon. Some of the Antients seemed not acquainted
with the Constellation Libra, and therefore they assigned
all the Space from Virgo to Sagittarius to the Possession of
Scorpio; and therefore Ovid says—*

*There is a Space above, where Scorpio bent
In Tail and Arms, surrounds a vast Extent;
In a wide Circuit of the Heavens he shines,
And fills the Space of two celestial Signs.*

Metam. II.

*This is also evident from Virgil's Compliment to Cæsar
Augustus; for when he proposes to him the Divinity of a
Constellation, he assigns him the vacant Place between
Virgo and Scorpio, in these Lines.—*

*Or wilt thou bless our Summers with thy Rays,
And, seated next the Virgin, poise our Days;*

*Where, in the Void of Heav'n, a Space is free
Betwixt the Scorpion and the Maid for thee;
The Scorpion ready to receive thy Laws
Yields half his Region, and contracts his Claws.*

Georg. I. *

Euphros. Well, I see Astronomy is useful, too, for understanding the Poets.—But what does *Sagittarius's* Bow denote? Is it not the hunting Season?

Cleon. You guess very right, my *Euphrosyne*; his *Bow* and *Arrow* point out the Sportsman, whose Season now commences.—

Euphros. But how comes he to be represented with the hinder Part an Horse?

Cleon. This is altogether owing to Fable; they tell us of a Centaur, whose Name was *Chiron*, the Son of *Saturn* and *Phillyra*, a learned Physician, and Preceptor to the famous *Achilles*; *Hercules's* Dart, dipped in the venomous Blood of the *Lernæan Hydra*, falling on his Foot, gave him an incurable Wound; he desired to die, but could not, being born of immortal Parents; who therefore took him up to Heaven, and made him a Constellation.

Euphros. What monstrous Things the Poets relate!—And pray, what say they of the next Monster, *Capricorn*, half Goat and half Fish?

Cleon. This Constellation had its Origin from the wild Goat, whose Nature being to seek its Food from the Bottom to the Top of Mountains, climbing from Rock to Rock, aptly emblemized the Ascent of the Sun, from the lowest Point in the Beginning of this Sign to its highest Pitch, or Summit in the Summer Solstice.—But the Poets feign, that a Goat suckled *Jupiter*, and that after it was dead, he made a Shield of its Skin, called *Ægis*, with which he singly combated the Giants.

At

* These Passages in *Ovid* and *Virgil* seem very strange, when we find them in other Places making Mention of *Libra* as a Sign of the Zodiac. And it is certain, that the Antients had the Sign of the *Balance* actually depicted on their Globes as long ago as it was at the autumnal *Equinox* (which is more than 2000 Years since), for there it appears on an old celestial Globe, found among the Ruins of ancient *Italy*, and kept in the *Farnesian Palace* at *Rome*, of which I have a Copy by me.

At length, he restored the Goat to Life again, gave her a new Skin, and placed her among the Constellations of Heaven. Others say, that *Pan*, a Man upwards and a Goat below, was at last changed into this Constellation, as being the God of the Woods and Shepherds, and Guardian of their Flocks. But as to the Fish-part of *Capricorn*, I take it to be a Fancy of modern Date.

Euphros. *Aquarius*, I see pouring his Water from Heaven; I'll venture to guess once more, that this Figure is an Emblem of a rainy Season.

Cleon. And you are very right; for *Virgil* uses the Term *Aquarius* (by a Metaphor) for *Winter*, as it is also translated by Mr. *Dryden*.—

This during Winter's drizzly Reign be done,

'Till Aries receives th' exalted Sun.

Georg. III.

But the Poets tell us, this *Aquarius*, when on Earth, was that beautiful Youth *Ganymede*, Son of *Tros*, whom an Eagle (sent by *Jupiter*) snatched off from Mount *Ida*, as he was hunting, and carried him into Heaven; where *Jupiter* made him his Cup-bearer, and whom he attends in all his Banquets with flowing Cups of Nectar.—Or thus, according to *Ovid*:

Disguis'd in Eagle's Plumes he downward flies,

And bears the Phrygian with him to the Skies;

There he for Jove (in Spight of Juno's Frowns)

The flowing Bowls with purple Nectar crowns.

Metam. X.

Euphros. The Evening grows late, *Cleonicus*; we have but just Time to enquire about the last of the twelve Constellations, which you call *Pisces*, or the *Fishes*; pray, tell me in brief their Original.

Cleon. The Fish, being at the Time when the Sun enters this Sign, most in Season, gave Occasion for the Denomination thereof; though the Poets tell us other Things: They give two Reasons for the Divinity of the *Fishes*:—The first is, because in the War with the Giants, *Venus* being disturbed, converted herself into a Fish;—the Second, because a Dove sat once upon the Egg of a Fish, in the River *Euphrates*, and at length hatched a Goddess of great Goodness, and merciful to Mankind. On both these Accounts the *Fishes* were held sacred, and placed among the Stars.—And let this

suffice, my *Euphrosyne*, for the Original and fabulous History of the Constellations of the Zodiac; the next Evening we will spend in pursuing the same Enquiries relating to the Constellations in the northern Hemisphere.

DIALOGUE III.

Of the CONSTELLATIONS of the Northern Hemisphere, with their ORIGIN, and Mythologic History.

Euphrosyne.

THE Pleasure of our last Conversation has made the Time seem long ere the next returned.— I must still expect to be indulged the Liberty (though tiresome) of continuing the Enquiries I have begun, in relation to the rest of the Constellations which I see spread over the Surface of the Globe. But, pray, which of them will it be proper to begin withal?

Cleon. Those of the Northern Hemisphere, or on the North Side of the Ecliptic; and then proceed to those on the Southern Side. These will give us Occasion to rehearse most of the pleasant Stories of the Poets and Fabulists, in relation to their fictitious Original, and this is all we must here expect.

Euphros. And which of these do you hold it proper to begin with?

Cleon. With the two Bears, viz. *Ursa Major* and *Ursa Minor*, as being the most northerly. The Greater of these was called *Arctos* and *Helice* by the Greeks; and the Lesser, *Cynosura*, because its Tail was like that of a Dog. The Greater of these Bears, was once the fair *Calisto*, Daughter of *Lycaon*, who being deflowered by *Jupiter*, was, by the Rage of *Juno*, turned into a BEAR; and her Son *Arcas* into the Lesser Bear; but the Disgrace was taken away by *Jupiter's* advancing them to Heaven, and making them two such remarkable Constellations. These Bears constantly circulate about the North Pole, and never go below our Horizon; on which Account, *Virgil*, speaking of *Draco*, and the Bears, says;

Around

*Around the Pole the spiry Dragon glides,
And like a winding Stream the Bears divides;
The Less and Greater, who by Fate's Decree,
Forbidden are to touch the Northern Sea.*

Georg. I.

For *Juno* being enraged at their being taken up into Heaven, desired *Tethys*, (the Goddess of the Ocean) that she would never suffer *Calisto* to bathe in her Waters.

*When Juno saw the Rival in her Height,
Spangled with Stars, and circled round with Light,
She sought old Ocean in his deep Abodes,
And Tethys, both rever'd among the Gods.
They ask what brought her there! "Ne'er ask, says she,
What brings me here, Heav'n is no Place for me.
You'll see, when Night has cover'd all Things o'er,
Jove's starry Bastard, and triumphant Whore
Usurp the Heav'ns; You'll see 'em proudly roll
In their new Orbs, and brighten all the Pole.
And who shall now on Juno's Altars wait,
When those she bates grow greater by her Hate?
I on the Nymph a Brutal Form impress'd,
Jove to a Goddess has transform'd the Beast;
This, This was all my weak Revenge could do:
But let the God his chaste Amours pursue,
And, as he acted after Io's Rape,
Restore th' Adulteress to her former Shape;
Then may he cast his Juno off, and lead
The great Lycaon's Offspring to his Bed.
But you, ye venerable Pow'rs, be kind,
And, if my Wrongs a due Resentment find,
Receive not in your Waves their setting Beams,
Nor let the glaring Strumpet taint your Streams."*
The Goddess ended, and the Wish was giv'n.—

Metam. II.

Euphras. But what is that terrible *Serpent*, or *Dragon*, you mention, which I also see between the *Bears*? And how came he there?

Cleon. This was the *Watch-Dragon*, which *Juno* appointed to keep the Garden of the *Hesperides*, three Daughters of *Hesperus*, Brother to *Atlas*. In these Gardens were Trees that bore golden Fruit, which *Hercules*

attempting to steal, first slew the *Dragon*, which was afterwards made this Constellation.

Euphros. On the other Side the *Lesser Bear*, I see some great Personages sure, *Cepheus* and *Cassiope*, *Perseus* and *Andromeda*; are not these very memorable Names in History?

Cleon. Yes, more especially so in fabulous History. *Cepheus* and his Wife *Cassiope* were King and Queen of *Ethiopia*, and *Andromeda* was their Daughter; she was bound to a Rock to be devoured by a Sea-monster, by the *Nymphs*, because her Mother *Cassiope* proudly preferred her Beauty to their's.—You see the Fetters on each Hand.—The unhappy Case of this fair Nymph reached the Ears of *Perseus*, Son of *Jupiter* and *Danaë*, who, with his Falchion, and Wings to his Feet (which you see), took his Flight through the Air to *Ethiopia*, where he slew the Monster, released *Andromeda*, and then married her. They were all afterwards placed among the Constellations, where they make some of the brightest in the Northern Hemisphere.—This remarkable Story is finely told by *Ovid*, which is in Part thus—

Now *Æolus*, the Ev'ning boist'rous Wind
Had in eternal Caves with Bars confin'd,
And *Lucifer*, bright Harbinger of Day;
Perseus, and all to Bus'ness call'd away:
When to his Feet again he lac'd his Wings,
Girt on his Falchion sure, and boldly flings
Thro' the wild airy Regions of the Skies,
And o'er a Thousand nameless Nations flies;
And, with a slight Survey, those Countries past,
He made th' *Ethiopian* Land at last.
There lay *Andromeda*, expos'd along,
Condemn'd to suffer for her Mother's Tongue,
Whom, when the sharp-ey'd, tow'ring Hero spy'd,
With Arms to rugged Rocks severely ty'd;
But that her flowing Tears her Life betray'd,
And that her Locks with fanning Breezes play'd,
She look'd a finish'd Marble-piece; but now
Soft flames in his unknowing Bosom glow.
Ravisht, amaz'd, he views the lovely Maid,
And half forgets his flying, airy Trade.

Then,

*Then, near her, takes the Rock, and, O! said he,
 Bright charming Creature, fitter far to be
 In some kind Lover's softer Arms enchain'd,
 Than with the Weight of barb'rous Fetters pain'd,
 Tell me, sweet Maid, thy Country's Name and thine,
 And why thee thus to Rocks these pond'rous Chains confine?*
*Silent a-while the blushing Virgin stay'd;
 Of manly Converse, rarely us'd, afraid;
 Only her Tears, which still she might command,
 In her fair Eyes like rising Fountains stand.
 Her snowy Hands her modest Looks had hid,
 But that rough Chains her snowy Hands forbid;
 Oft ask'd, (lest Silence should her Guilt accuse)
 At last she both her Name and Country shews.
 Scarce Half her Tale was told, when sounding Waves
 Her Fate forebiew, the hideous Monster laves
 His Sides with Seas, which to his Passage yield,
 And whelms his Bulk o'er half the wat'ry Field.
 The Maid shrieks out; her mournful Father cries:
 Her Mother too with equal Complaints replies,
 Both wretched now; but much more justly she,
 Whose vainer Pride deserv'd her Misery.
 No help, alas! but useless Tears they bring,
 And, crying, round their fetter'd Daughter cling;
 When Perseus thus; Weep thus no more in vain,
 Few Minutes only now for Help remain.
 Should I, fair Danaë's Son by thund'ring Jove,
 Perseus, the Offspring of his golden Love;
 Perseus, Medusa's Conqueror, should I,
 Who thro' the Air with certain Pinions fly;
 Should I your Daughter for a Wife demand,
 I sure might in your choice the fairest stand.
 But I to those will greater Merits join,
 If Heav'n but second now my bold Design;
 And beg her as my Love's victorious Deed,
 If now from Death by my Assistance freed.
 His Offer gladly both with Prayers embrace;
 For who'd refuse it in that desp'rate Case?
 And, for a Dow'ry too, that Crown engage,
 Too weighty grown for their declining Age.
 Now, as some Galley, forc'd with Oars and Tides,
 Plows up the Ocean with its foaming Sides;*

So the prodigious Monster's horrid Force,
 Breaks up the Waves with an impetuous Course,
 And now no farther off than one might fling
 A Bullet with a Balearian Sling,
 The gallant Youth, with sudden Motion, springs
 From Earth, and cuts the Air with active Wings;
 And as the how'ring Hero's martial Shade,
 With Tremblings on the wat'ry Surface play'd,
 The Beast enrag'd at the thin Phantom grew,
 And at the Shade with utmost Fury flew.
 But as Jove's Bird, when from a Cloud he spies,
 Where on some Plain a Dragon basking lies,
 Stoops, at his Back, and to prevent his Jaws,
 Thro's scaly Neck his crooked Pounces draws;
 So he the Air with nimble Wings divides,
 And plies the Monster's Back and rolling Sides;
 And with a lucky Thrust his shoulder rives,
 And up to th' Hilt, his greedy Falchion drives.
 Struck with so deep a Wound, the Monster raves,
 And fiercely bounds above the 'frighted Waves;
 Then dives again, and with a dreadful Sweep,
 With thick black Gore distains the boiling Deep.
 And as a Boar, which eager Hounds engage,
 So ev'ry Way he vents his baffled Rage:
 While from his Fangs the wary Perseus flies,
 And ev'ry Way the furious Monster plies.
 Now on his Back and Ribs like Anvils beats:
 Now on his Fish-like Stern his Strokes repeats.
 The Beast then spouts such Floods of wat'ry Gore,
 Perseus durst trust his dabbled Wings no more.
 But spies a Rack, which bare in Calms might lie,
 But under Water when the Sea ran high.
 There straight the fearless Hero takes his Stand,
 And grasps the Summit with his swordless Hand;
 And then, to crown his Conquest, strongly foins,
 And thrusts his Sword oft thro' the dying Monster's Loins,
 Now, for the Conquest, mighty Shouts and Cries
 Ring round the Shores, and echo to the Skies.
 With Joy Calliope and Cepheus rais'd,
 Him as their Son receiv'd, his Actions prais'd;
 Call'd him their Family's Support and Stay,
 On whose brave arms their Hope and Safety lay.

The

*The lovely Maid moves on, now freed from Chains,
The Cause, and fair Reward of all his Pains.*

Metam. Book IV.

Euphras. That is indeed a very beautiful Description.—
But what, or whose is that frightful, ill-favoured Face
Or He d, which *Perseus* holds in his left Hand? And
what are those Snakes that proceed like Hair from it?

Cleon. That Constellation is called *Caput Medusæ*, or,
the Head of *Medusa*: This *Medusa* was once the fair
Daughter of *Phorcus* and *Cete*, who had golden Hair;
her Charms tempted *Neptune* to violate her Chastity in the
Temple of *Minerva*, which that Virgin Goddess so
resented, that she changed the Hair of *Medusa* into Snakes,
and such, that whosoever looked on them were turned
into Stones; therefore the Gods, out of pity, sent *Perseus*
to cut off her Head; which he did, and gave it to be
placed in the Shield of *Pallas* and *Minerva*. This Story
is also finely told by the same Poet:—

*Medusa once was for her Beauty fam'd,
At whom a Thousand jealous Suitors aim'd;
But more than all, her lovely Tresses charm'd,
Whose golden Beams her coldest Lovers warm'd,
(I've met with some who waited at her Court,
And only Wonders of her Locks report)
Her Neptune seiz'd, with lustful Passions wild,
And in the chaste Minerva's Fane desl'd:
The Virgin Goddess turn'd aside, and held
Before her modest Eyes the sacred Shield;
But that the Crime might be in one reveng'd,
To horrid Snakes Medusa's Curls she chang'd,
And that she might in future rolling Years
O'er-awe the vicious World with pow'rful Fears,
The Snakes she made still in her Shield she bears.*

Metam. Lib. IV.

This *Medusa* was one of those three horrid Monsters
of Hell, called *Gorgons*; who slew People with their very
Looks; the Names of the other Two were *Stheno* and
Euryale, all Daughters of *Phorcus*. From the Blood
which gushed out on striking off *Medusa's* Head sprang
Pegasus, or the winged Horse, which you see depicted
(the Fore-part) above the Equinoctial, a little below
Andromeda.

Euphros. I see him—and, pray, what Stories do the Fabulists tell of this singular Horse? and how came He in Heaven?

Cleon. This Horse belonged to the *Muses*, who let him sometimes to the Heroes and Demi-gods, for greater Expedition; this Horse *Perseus* rode; and at last, *Bellerophon* mounting him, was carried through the Heights of Air, where being seized with Fear and a Vertigo, he fell to the Earth, and the Horse was made a Constellation in the Heavens. To this *Milton* alludes in his Invocation of *Urania*, in the Beginning of the 7th Book of *Paradise Lost*.

—————Up led by thee
 Into the Heav'n of Heav'ns I have presum'd,
 An earthly Guest, and drawn empyreal Air,
 Thy Temp'ring; with like Safety guided down
 Return me to my native Element;
 Lest from this flying Steed unrein'd, (as once
 Bellerophon, though from a lower Clime)
 Dismounted, on th' Aleian Field I fall
 Erroneous there to wander and forlorn.

Euphros. The next that makes a considerable Figure on the Globe, is *Auriga*; pray, who was he, and how came the Kids in his Hand behind them?

Cleon. Who he was, or how he came by these Kids is hard to say; Mythologists are quite silent about him; Unless they intend *Phaëton*, who by *Ovid* is called the Charioteer of *Phæbus*, or the Sun; or else he was some distinguished person among the Chariot-drivers in Races, so much celebrated among the ancient Greeks and Romans; and such *Manilius* seems to represent him in the following Lines:—

But when the Ram first shews thrice five Degrees,
 The Driver rears his Chariot from the Seas;
 And climbs that Steep, whence blust'ring Boreas brings
 His North-east Blast, and shakes their freezing Wings.
 He keeps his own Concern, and thence bestows
 Those various Arts which here on Earth he chose.
 To drive the Chariot, to direct the Course,
 And bang with forward Lashes on the Horse;
 Now press directly, now wheel nimbly round,
 Out-strip the Wind, nor raise the dusty Ground;

*Or cross athwart, and force the Rest to yield,
Disperse the Croud, and clear the gaping Field;
And though out-stript, yet scorn to stop to Fear,
But, drive on Hope, and leave behind Despair.
Or, 'midst the Race from Horse to Horse to leap,
Sport o'er their Backs, and fix the dangerous Step:
Or, singly mounted, break the foaming Jaws,
Throw well the Dart, and force a just Applause.*

Astr. Book V.

Euphros. Be *Auriga* whom he will, the Poet makes a pretty Use of the Story.—But pray, *Cleonicus*, who is that old Fellow *Boötes*, with a frizly Beard, standing with one Foot on *Mount Mænalaus*, holding a Club in one Hand, and two Coursers in a String with the other?

Cleon. His Name implies an *Herdsmen*; but he is more properly called *Arctophylax*, or the *Bear-keeper*; for he constantly follows the *Greater Bear* in its daily Rotation about the North Pole. Also because the *Bear* is sometimes called the *Waggon*, *Boötes* is mostly called the *Waggoner*, by the Poets; thus *Ovid*:

*Now Silence o'er the slumb'ring World did reign,
And slow Boötes had declin'd his Wain.*

Myrrha pursues her Guilt.———

Metam. Book X.

And in the Story of *Phaëton*, he thus describes the Consternation of the *Serpent* and *Boötes*.—

*The folded Serpent next the frozen Pole,
Stiff and benumm'd before, began to roll,
And rag'd with inward Heat, and threaten'd War,
And shot a redder Light from ev'ry Star.
Nay, and 'tis said, Boötes too, that Thou
Wouldst fain have fled, tho' cumber'd with thy Plough.*

Book II.

Euphros. The *Swan*, I see, makes the next considerable Figure; he is in a Posture of Flight, in the *Milky Way*; for what Reason could a *Swan* come there, *Cleonicus*?

Cleon. Ah, my *Euphrosyne*, while we are on the fabulous Part of Astronomy, Fiction is all the Reason you must expect in Things. And so ridiculous are the Fables for the most Part, that *Jove* is pretended to have assumed the Shape of a *Swan*, in order to deceive *Leda*, the Wife

of

of *Tyndarus*; which adulterous Story is thus commemorated by *Manilius*, who speaks of this Constellation.

*Next view the Swan, which Jove advanc'd above,
That Form's reward by which he caught his Love.
When shrouded in the fair, deceitful Shape,
He cheated trusting Leda to a Rape:
Now grac'd with Stars, his Wings stretch't o'er the Skies.*

Book I.

Euphros. But I see a much nobler Bird yet, below the *Swan*, I mean the *Eagle*; no Doubt but there was some notable Occasion for his being made a Constellation.—

Cleon. The *Eagle* being King of Birds, as *Jupiter* was of the Gods, it was always esteemed sacred to that supreme Deity, and was usually called the *Bird of Jove*. The Poets feign, that *Jupiter* was brought up in a Cave in *Crete*, by Doves, who fed him with *Ambrosia*, and an *Eagle*, who supplied him with *Nectar*, which he drew from a Rock and carried in his Bill; for this he was honoured with celestial Dignity.—Others say, that in the Wars of the Giants, the *Eagle* brought Thunder to *Jupiter*, with which he quelled them; and is therefore called *Jove's Armour-bearer* by *Virgil*.—Of the *Eagle* as a Constellation, *Manilius* thus speaks:

*The tow'ring Eagle next doth boldly soar,
As if the Thunder in his Claws he bore;
He's worthy Jove, since he, a Bird, supplies
The Heav'n with sacred Bolts, and arms the Skies.*

Book I.

Euphros. Who is that old Fellow *Serpentarius*, grasping an hideous Serpent in his Hands?

Cleon. Some think he represents *Æsculapius*, the God of Physicians and Physic; he was worshipped at *Epidaurus*, his Birth-place, first, and afterwards at *Rome*, in the Form of an huge Serpent.—Others think it is *Hercules*, who, while an Infant, destroyed with the Grasp of his Hands two Serpents, sent by *Jupiter* to kill him in the Cradle: Hence *Ovid*—

*You kill'd two Serpents with your Infant Hand,
Which then deserv'd Jove's Scepter to command.* Epist.

Of

Of this Constellation, thus *Manilius*:—

*Next Ophionius strikes the mighty Snake,
Untwists his winding Folds, and smooths his Back,
Extends its Bulk, and o'er the slipp'ry Scale,
His wide-stretch'd Hands on either Side prevail;
The Snake now turns his Back, and seems to rage;
That War must last where equal Pow'rs engage.*

Book I.

Euphras. What is *Hercules* about, in that kneeling Posture? What means the Club in his Right-hand, the three-headed Monster in his Left, and the Lion's Skirt hanging over his Arm?

Cleon. This represents some of the Labours of that wonderful Demi-god, who was the Son of *Jupiter*, by *Alcmena*, the Wife of *Amphitryo*, King of *Thebes*. As he was the greatest Hero for Feats of Strength; so, no Doubt, his Fable had its Origin in the History of *Samson*.—The Labours of *Hercules* were many, of which twelve are particularly celebrated, and are contained in the twelve following Verses:

—The Cleonean Lion first he kills,
With Fire and Sword then Lerna's Hydra quells;
Of the wild Boar he clears th' Er'manthean Fields.
The Brass-foot Stag with golden Antlers yields.
He Stymphe clears of Men devouring Birds,
And next the bouncing Amazon ungirds;
The Stables of King Augeas he cleans,
The Cretan Bull he vanquishes and chains:
Diomedes's Horses him their Conqueror own,
Then he brings low three-headed Gerion;
Hesperian Apples next his Name advance,
And his last Labour Cerberus enchains.

Of the Lion's Skin he made a Shield, and Breast-plate, which you see; that three-headed Monster is *Cerberus*, the Dog who kept the Gate of Hell, and whose Body was cover'd with Snakes instead of Hair; of whom *Virgil* thus speaks:—

*Stretch'd in his Kennel, monstrous Cerb'rus round
From triple Jaws made all these Realms resound.*

And *Horace* thus:—

*Hell's grisly Porter let you pass,
And frown'd and listen'd to your Lays.*

The

*The Snakes around his Head grew tame;
His Jaws no longer glow'd with Flame;
Nor triple Tongue was stain'd with Blood:
No more his Breath with Venom flow'd.*

Book III. Ode ii.

Euphras. Well, to pass this Monster a little, I observe
Lyra on the Breast of an Eagle, what does that import?

Cleon. *Lyra* is the Lyre, or Harp of *Orpheus*, the Son of *Apollo*, by *Calliope* the *Muse*; on which he is said to have played and sung so sweetly, that he tamed wild Beasts, stayed the Course of Rivers, and made the Woods follow him.—Yea, when he descended into Hell to fetch back his Wife *Eurydice*; he charmed *Pluto* and *Proserpina* (King and Queen of Hell), and made the Damned dance, if what *Virgil* says be true:—

*Th' unhappy Husband, Husband now no more,
Did on his tuneful Harp his Loss deplore,
And sought his mournful Mind with Music to restore.
On thee, dear Wife, in Deserts all alone,
He call'd, sigh'd, sung, his Griefs with Day begun,*

*Nor were they finish'd with the setting Sun.
Ev'n to the dark Dominions of the Night
He took his Way, thro' Forests void of Light;
And dar'd amidst the trembling Ghosts to sing,
And stood before th' inexorable King.*

*Th' infernal Troops like passing Shadows glide,
And, list'ning, crowd the sweet Musician's Side.
Ev'n from the Depths of Hell the Damn'd advance,
Th' infernal Mansions nodding seem to dance;
The gaping three-mouth'd Dog forgets to snarl,
The Furies hearken, and their Snakes uncurl:
Ixion seems no more his Pains to feel,
But leans attentive on his standing Wheel.*

Georg. IV.

With *Orpheus* 'tis usual to join the Story of *Amphion*, the Son of *Jupiter*, by *Antiope*; he received a Lute, or Harp, from *Mercury*, the Sound whereof moved the Stones so regularly, that they composed the Walls of the City of *Thebes*, according to *Horace*.—

Amphion too, as Story goes, could call
Obedient Stones to make the Theban Wall;

He

*He led them as he pleas'd, the Rocks obey'd,
And danc'd in Order to the Tune he play'd.*

Art of Poetry.

Euphros. How extravagant are the Fictions of the Poets! They could never propose to have Credit for such Romances; what could they propose, then, *Cleonicus*, in such wild Relations?

Cleon. Their End was to shew their Invention, exercise their Art, amuse the Learned, delude the Ignorant, and sometimes to convey moral Instructions in this fabulous and hyperbolical Way, which was much in Vogue in the early Ages of the World. Thus, all they would imply by the wonderful Account of *Orpheus* and *Amphion*, is, that they were so eloquent, as to persuade the wild and savage People of their Time to live conformable to the Laws and Rules of civil Society.

Euphros. How came the Dolphin to merit a Place among the Stars? Methinks they made Fish plenty in Heaven! —

Cleon. The Heaven of the Heathen, was a common Receptacle of every Thing; a wild Miscellany of all Orders of Creatures, without Order or Distinction. — But not to digress; the Poets tell us of one *Arion*, a Lyric Poet of *Lesbos*, who got great Riches by his Art; and as he was going to *Italy*, the Mariners attempted to rob him, but he desired he might play one Tune on his Harp before they threw him into the Sea; he played, and then leaped into the Sea, where a Dolphin (drawn thither by the Sweetness of his Music) received him on his Back, and carried him to *Tenedos*, with all his Money; for which Kindness the Dolphin was made a Constellation, according to *Ovid*.

*The Gods beheld the gen'rous Deed, and Jove
Advanc'd him from the Deep to shine above
Among the Constellations, now divine,
And for his Share of Stars, he gave him nine.*

Lib. Fast. II.

Euphros. What is this *Coma Bereniceæ*, just above *Virgo*?

Cleon. It is the Hair of *Berenice*, the Wife of King *Euergetes*, who vowed to cut off her Hair if her Husband returned from the War Victor; accordingly she did,
and

and sent it to the Temple of *Venus*, from whence it was said to be taken up into Heaven and made a Constellation: On which *Catullus* has wrote a curious Poem in *Latin*.—

Euphros. The Evening is now so far spent, that there is no Time for any farther Enquiries; and indeed, if it were not, I believe I have pretty well tired you with Queries for to Night.

Cleon. Not at all, my *Euphrosyne*; but luckily for us, we have taken Notice of all that afford any Thing of History or Fable in the Northern Constellations, worth Notice; the rest are of more modern Invention, and have nothing in them significant. We will, To-morrow, pass on to the Southern Constellations, which will afford us farther Entertainment of this Sort, and conclude this Survey.

DIALOGUE IV.

Of the CONSTELLATIONS of the SOUTHERN HEMISPHERE, with their FABULOUS HISTORY.

Euphrosyne.

THIS Evening you appoint for finishing our View of the Constellations.—We are now to descend to those of the Southern Hemisphere, among which, I see *Orion* make a very considerable Figure; pray, *Cleonicus*, give me his Story.

Cleon. I will, and it runs thus in Fable; 'tis said that *Jupiter*, *Neptune*, and *Mercury*, as they once travelled together, were benighted, and forced to lodge in a poor Man's House, whose Name was *Hircus*; he entertained them as well as he could, which so pleased the Gods, that they promised to grant whatever he asked. He said, he promised his Wife on her Death-bed to live a Widower, and yet he extremely desired to have a Son; they consented to his Request, and moistening an Ox's Hide with their Urine, they commanded him to bury it ten Months. After which Time, digging it up, he found in it a new-born Child, which from thence was called *Urien*, or *Orion*.

Orion was a constant Companion of *Diana*, while a Youth, but at length, behaving indecently to her, he was stung to Death by a Scorpion. However, *Jupiter* translated him to Heaven, and made him a most conspicuous Constellation, which is thus described by *Manilius*:

*First, next the Twins, see great Orion rise,
His Arms extended stretch o'er Half the Skies:
His Stride is large, and with a stately Pace
He marches on, and measures a vast Space.
On each broad Shoulder a bright Star's display'd,
And three obliquely grace his hanging Blade.
In his vast Head immers'd in boundless Spheres,
Three Stars less bright, but yet as great, he bears.
But farther off remov'd, their Splendor's lost,
Thus grac'd and arm'd, he leads the starry Host.*

Book I.

Euphros. The next Constellation I observe, is the huge *Whale*, or rather *Sea-monster*; for he is partly *Beast*, and partly *Fish*. How came he in Heaven, pray?

Cleon. This is that dreadful Monster which was to devour *Andromeda*, chained to a Rock; whose Story I have before related to you from *Ovid*. The *Whale* is thus described by *Manilius*:—

*Next on his Belly floats the mighty Whale,
He twists his Back, and rears his threat'ning Tail;
He spouts the Tide, and cuts the foaming Way,
Wide gapes his Mouth, as eager on his Prey;
Such on *Andromeda* he rush'd, and bore
The troubled Waves beyond their usual Shore.*

Book I.

Euphros. What horrid *Hydra* is that which carries such a Length on the Globe?

Cleon. It makes indeed, a great Figure, but I cannot certainly tell its Original.—I should have taken it for the *Hydra* of the Lake *Lerna*, which *Hercules* slew, but this has but one Head, whereas that is said to have had many; of which it is said, that when any one was cut off, another immediately sprang up in the Place of it, unless the Blood which issued from the Wound was stopped by Fire; this *Hercules* did by the Assistance of

Iolaus, the Son of *Iphiclus*, and so slew the Serpent.—
Iolaus, you'll find by *Ovid*, was no Loser by this; for
 when he was grown old and decrepit, he was restored to
 Youth again by the Prayers of *Hercules*.

At the big Entrance, Iolaus appears,
Blooming in Beauty, and renew'd in Years;
Crown'd with a second Youth, and sprightly Grace,
The doubtful Down scarce shades his maiden Face.
The Favour to his Uncle's Pray'rs he ow'd,
And Hebe at her Husband's Suit bestow'd.

Met. Lib. IX.

Euphros. Strange Things, sure, have been done of
 old: If our *Jugglers*, or *Legerdemain Gentlemen*, could
 perform any Feats like this, they would be in better
 Repute among the People than now they are.—But
 that *Dog*, there, with a *Collar* about his Neck, how
 came he in Heaven? And that little one above is so very
 pretty, that I should almost fancy it to be a Lap-dog
 belonging to some of their celestial Ladyships, if I
 thought any such Thing were the Fashion in Heaven.—

Cleon. You cannot think any Thing too wild or
 whimsical, that may not be true, of those whom the
 Ancients have advanced to their poetical Heaven: And
 in this Particular of the *Dog*, you have conjectured right:
 for Poets tell us, this was the *Dog* that belonged to
Icarus, or rather to his Daughter *Erigone*, who, as some
 will have it, was made the Sign *Virgo*; and it was per-
 mitted her, no Doubt, to take her *Dog* along with her
 to Heaven.—But, be that as it will, this is certain, no
 Constellation was more notable than this among the
 Ancients, on Account of that most obvious and remark-
 able Star in his Mouth, of which I shall say more an-
 other Time.

Euphros. Pray, what mathematical Instrument is that
 which I see between the *Lion* and the *Hydra*?

Cleon. It is the Sextant of *Urania*, one of the *Nine*
Muses; it is placed there in Honour of her, as Inven-
 tress, not only of that, but most other astronomical In-
 struments, and the Patroness of Astronomers and the
 celestial Sciences.—Hence the Poets, when they under-
 take to sing of Heaven, and the Works of Nature,
 invoke the Aid of *Urania*, as *Milton*:

Descend

*Descend from Heav'n, Urania! by that Name
If rightly thou art call'd, whose Voice divine
Following, above th' Olympian Hill I soar,
Above the Flight of Pegasean Wing—*

And the Author of *Universal Beauty*, Mr. Brooks, thus invokes this Goddess:

*—Thou, whom the ancient Seer stiles
Venus Urania! born the Babe of Smiles;
When from the Deep thy bright Emergence sprung,
And Nature on thy Form divinely hung,
Whose Steps (by Loves and Graces kiss'd) advance,
And chearful Hours lead on the sprightly Dance;
While Time within eternal Durance bound
Harmonious, on golden Hinges moves around:
Such, Goddess! as when Silence wond'ring gaz'd,
And ev'n thyself beheld Thyself amaz'd;
Such hap'ly by that Coon Artist known,
Seated apparent Queen on Fancy's Throne;
From thence thy Shape his happy Canvas blest,
And Colours dipt in Heav'n, thy heav'nly Form confess.
Such, Goddess! thro' this Virgin Foliage shine,
Let kindling Beauties glow thro' ev'ry Line,
And ev'ry Eye confess the Work divine.—*

Part I.

Euphros. What is meant by the Word *Crater*? The Figure of the Constellation seems to me like a rich two-handled Cup, or Bowl.

Cleon. That is the very Thing; it was the Bowl of *Bacchus*, the God of Banquets and Revels. Next which, you see *Corvus*, the Raven, or Crow, sitting on the Serpent's Tail. Below these, you observe another of those Monsters they call *Centaur*s, striking his Spear into a Wolf; and next to him is *Ara*, the Altar of *Jove*; the Use and Occasion thereof is thus described by *Manilius*:

*The World's great Temple next, and Altar lies,
Grac'd with the Gifts of conqu'ring Deities;
When Earth-born Giants did their Skies invade,
The lesser Gods implor'd the greater's Aid;
His Pow'r Jove doubted when he view'd from far
The threat'ning Force of the unequal War.
When he inverted Nature's Frame beheld,
That Earth rose upward, and that all rebell'd:*

*That Hills on Hills heap'd, rais'd their threat'ning Head,
 And frighted Stars approaching Mountains fled:
 When impious Armies at a monst'rous Birth,
 Broke thro' the Bowels of the gaping Earth,
 Of disagreeing Forms, and frightful Makes,
 Vast human Bodies twisted into Snakes,
 Ere this no Danger and no Fear was known,
 And wanton Jove sat idly in his Throne.
 But lest some greater Pow'r (soft Ease betray'd,
 His Mind to Doubt) should yield the Rebels Aid;
 He rais'd this Altar, and the Form appears,
 With Incense loaded, and adorn'd with Stars.*

Lib. I.

Euphros. What great Ship is that I see, called *Argo*?

Cleon. This was the Ship in which the famous Expedition was made by *Jason* and his Company (hence called *Argonauts*) to *Colchis*, to recover the *Golden Fleece*; and is thus described by *Manilius*:——

*Next Procyon view, and next the nimble Hare,
 Then Argo sailing thro' the liquid Air;
 Advanc'd from all the Dangers of the Tides,
 Which first she stemm'd, she now securely rides.
 Heav'n is her Port, and now she rules the Floods,
 A Goddess made for saving of the Gods.*

Lib. I.

Euphros. I see the *Peacock* is honoured with an Asterism likewise, how came that to pass?

Cleon. You have now quite puzzled me—I cannot tell how it came about, unless it was in Commemoration of *Argus*, whom the Poets feign to have had an hundred Eyes, two of which slept by Turns, while the others watched; as is thus described by *Ovid*:——

*Argus's Head an Hundred Eyes possess'd,
 And only two at once declin'd to Rest;
 The others watch'd, and in a constant Round,
 Refreshment in alternate Courses found;
 Where'er he turn'd, he always Iô view'd,
 Iô he saw, tho' she behind him stood.*

He was slain at last by *Mercury*, and turned by *Juno* into a *Peacock*, who placed his Eyes in the Tail of that Bird.

There

There Argus lies; and all that wond'rous Light
 Which gave his Hundred Eyes their usual Sight,
 Lies bury'd now in one eternal Night.
 But Juno, that she might his Eyes retain,
 Soon fix'd 'em in her gaudy Peacock's Train.

Metam. Lib. I.

Euphros. This is pretty much of a Piece with other poetical Stories.—But as I remember to have read, that the Peacock was a Bird sacred to *Juno* (as the Eagle to *Jupiter*), I could not tell whether it might not be on that Account.

Cleon. That may probably be the Case; *Juno* was Supreme of the Goddesses, and her Chariot was drawn by two Peacocks; no Wonder therefore, if this Bird was made a Constellation, and I only think 'tis Pity they had not placed him in such a Part where he might oftener appear, and have a greater Number of Stars to bedeck his Tail.

Euphros. Well, to pass him, what say you of the River *Eridanus*, I see there? Is it a River of *Nectar* that supplies the Gods with Drink? or what is it, and how came it there?

Cleon. The River *Eridanus* was that which is now called the *Po*, in *Italy*; it was placed in Heaven, in Commemoration of the unhappy Fall of *Phaëton*, (whose Name at first was *Eridanus*) the Son of *Apollo* and *Clymene*. The Fable is this; *Phaëton* wanted *Apollo* to give him some Proof that he was his Father. *Apollo*, to gratify his Son, bid him ask what he would, and it should be granted him, and swore by the River *Styx*, to confirm it, (which Oath is inviolable.) *Phaëton* asked Leave to drive his Chariot for one Day; which rash Request greatly grieved *Apollo*, who desired him not to insist on it, but in vain, for drive the Chariot he would, and *Apollo* by his Oath was obliged to permit him. So up he mounts, and drives on, regardless of his Father's Directions; but the Horses, not finding their usual Conductor, took Head, and the Charioteer being dazzled with the Light above, and frightened with the horrid Abyss beneath, and the terrible Scorpion, let go the Reins, lost his Way, and would have burnt one Half of the World, and froze the other, if *Jupiter* had not struck him with a Thunder-

bolt into the River *Eridanus*. This Story is the most noble and sublime of any in *Ovid*, and well worth your reading; the Conclusion of which runs thus:

Jove call'd to witness ev'ry Power above,
 And e'en the God whose Son the Chariot drove;
 That what he acted, he was forc'd to do,
 Or universal Ruin would ensue.
 He then ascended the ætherial Throne,
 From whence he us'd to hurl the Thunder down;
 From whence his Show'rs and Storms he us'd to pour,
 But now could meet with neither Storm nor Show'r.
 Full at his Head he shot the flaming Brand,
 Which stop't the Flames, and Fire with Fires restrain'd.
 At once from Life, and from the Chariot driv'n,
 Th' ambitious Youth fell Thunder-struck from Heav'n;
 The Horses started with a sudden Bound,
 And flung the Reins and Chariot to the Ground.
 The fludded Harness from their Necks they brake,
 Here fell a Wheel, and here a Silver Spoke;
 Here were the Beam and Axle torn away,
 And, scatter'd o'er the Earth the shining Fragments lay.
 The blasted Phaëton with flaming Hair,
 Shot from the Chariot like a falling Star;
 Which in a cloudless Ev'ning from the Top
 Of Heav'n drops down, or seems at least to drop;
 'Till on the Po his smoking Corpse was hurld,
 Far from his Country, in the western World.

Ovid's Met. Lib. II.

Euphros. This is a fine Relation indeed, though fabulous; and I suppose was intended to admonish us of the ill Consequences of rash and imprudent Actions. But what is the Meaning of the *Phoenix* in the Flame, which I see upon the lower End of the River *Eridanus*?

Cleon. That Bird too is a Fiction; of which *Pliny* thus writes; that she is of the Bigness of an Eagle, and never but one; that she lives 660 Years, and then makes a Nest of Hot Spices, which being set on Fire by the Heat of the Sun, she is burnt, and out of her Ashes there arises a Worm, which afterwards comes to be a *Phoenix*. This we have elegantly described by *Ovid* thus:
 Thus all receive their Birth from other Things,
 But from himself the Phoenix only springs;

Self-

*Self-born, begotten by the Parent Flame,
 In which he burn'd another and the same:
 Who not by Corn or Herbs his Life sustains,
 But the sweet Essence of Amomum drains;
 And watches the rich Gums Arabia bears,
 While yet in tender Dew they drop their Tears.
 He (his five Centuries of Life fulfill'd)
 His Nest on Oaken Boughs begins to build,
 Or trembling Tops of Palm; and first he draws,
 The Plan with his broad Bill and crooked Claws,
 Nature's Artificers; on this the Pile,
 Is form'd, and rises round: Then with the Spoil
 Of Cassia, Cinnamon, and Stems of Nard,
 For Softness strew'd beneath, his fun'ral Bed is rear'd.
 Fun'ral and bridal both; and all around,
 The Borders with corruptless Myrrh are crown'd;
 On this incumbent, 'till ethereal Flame,
 First catches, then consumes the costly Frame;
 Consumes him too as on the Pile he lies;
 He liv'd in Odours, and in Odours dies.
 An Infant Phoenix from the Former Springs
 His Father's Heir, and from his tender Wings
 Shakes off his Parent-Dust: His Method he pursues,
 And the same Lease of Life on the same Terms renews.
 When, grown to Manhood, he begins to reign,
 And with stiff Pinions can his Flight sustain,
 He lightens of its Load the Tree that bore
 His Father's royal Sepulchre before,
 And his own Cradle; this, with pious Care,
 Plac'd on his Back, he cuts the buxom Air,
 Seeks the Sun's City, and his sacred Church,
 And decently lays down his Burden in the Porch.*

Dryd. Ovid.

Euphros. A very surprising Account, were it true!—
 Pray, what is that other Bird called the *Toucan*?

Cleon. Indeed I can say but little of it, it is an *Indian* Bird; but how he, or the *Phoenix*, or the *Indian*, or the *Crane*, the *Sword Fish*, *Noah's Dove*, and other Constellations not named, came by their Divinity, I cannot particularly say. 'Tis certain they are all of them of modern Date, since *Manilius*, the ancient astronomical Poet, says not a Word of them; nor indeed were the

Stars of the Southern Hemisphere, near the South Pole, known in the Registers of Astronomy 'till within a few Centuries past. And as they became discovered and reduced to Constellations, the Astronomers gave them the Figures of such Creatures as they pleased. So that there remains now no more Constellations, of which we may expect any poetical Account, unless we reckon the *Milky Way* as such; for that we find the Poets very often exercised their *Muse* upon.

Euphros. You have already given me the true astronomical Account of the *Milky Way*; but it will be some Curiosity to hear what the Poets say, or feign, on that Head, and therefore pray oblige me so far.

Cleon. I will; *Hercules*, I have told you, was *Jupiter's* Bastard Child, by *Alcmena*, the Wife of *Amphitryo*, King of *Thebes*, and therefore he was the Object of *Juno's* Hatred. But after many Ways attempting to destroy him in vain, she was at length, by the Mediation of *Pallas*, reconciled to the noble Babe, and let him suck her Breasts, which he hurt by sucking too violently; wherefore she put him away, and some of the Milk was spilt, but it was not lost; for some of it fell upon the Sky, and running along, made the *Milky Way*. Some of it passed through the Clouds, and fell on the Earth, and where it fell, Lilies sprang up, which are therefore white, and were by some called the *Roses of Juno*. This is the Fable; the poetical Description of the *Milky Way* I have given you already. To which I shall add the various Opinions of the Ancients concerning the Origin of the *Milky Way* from *Manilius*, who relates them in the following Lines.

*Fond Men the sacred Causes strive to find,
And vainly measure with a feeble Mind;
And yet they strive, they madly whirl about
Thro' various Causes, still condemn'd to doubt
Whether the Skies grown old, here shrink their Frame,
And thro' the Chinks admit an upper Flame:
Or, whether here the Heavens two Halves are join'd,
As oddly clos'd, still leave a Seam behind;
Or here the Parts in Wedges closely press,
* the Frame, are thicker than the rest;
Like*

Like Clouds condens'd appear, and bound the Sight,
 The Azure being thick'n'd into White.
 Or whether that old Tale deserves our Faith,
 Which boldly says, that this was once the Path
 Where Phœbus drove; and that in Length of Years,
 The heated Track took fire and burnt the Stars.
 The Colours chang'd, the Ashes strew'd the Way,
 And still preserve the Marks of their Decay:
 Besides, Fame tells, by Age Fame rev'rend grown,
 That Phœbus gave his Chariot to his Son,
 And whilst the Youngster from the Path declines,
 Admiring the strange Beauty of the Signs;
 Proud of his Charge, he drove the fiery Horse,
 And would out-do his Father in his Course.
 The North grew warm, and the unusual Fire
 Dissolv'd its Snow, and made the Bears retire;
 Nor was the Earth secure, each Country mourn'd
 The common Fate, and in its Cities burn'd.
 Then from the scatter'd Chariot Light'ning came,
 And the whole Skies were one continu'd Flame.
 The World took Fire, and in new kindled Stars,
 The bright Remembrance of its Fate it bears.
 Thus Fame; nor must the softer Fable die,
 That Juno's Breast o'erflowing stain'd the Sky,
 And made that Milky-Way, which justly draws
 Its Name, the Milky Circle, from its Cause.
 Or is the spacious Bend serenely bright
 From little Stars, which there their Beams unite,
 And make one solid and continu'd Light?
 Or Souls, which, loos'd from th' ignoble Chain
 Of Clay, and sent to their own Heav'n again,
 Purg'd from all Dross by Virtue, nobly rise,
 In Æther wanton, and enjoy the Skies.

Book I.

And thus we have finish'd a fabulous Survey of the
 Constellations: That which now remains, is to proceed
 to a more particular Use of the *Celestial Globe*; and that
 shall be the Subject of our next Leisure.

DIALOGUE V.

Shewing the Use of the CELESTIAL GLOBE in solving SOLAR PROBLEMS, or such as relate to the SUN.

Euphrosyne.

ACcording to your proposed Method, I am now to learn the Use of the CELESTIAL GLOBE more accurately than I have yet done; but pray, *Cleonicus*, in what Respects, or in what Particulars, may I now expect to be instructed?

Cleon. I shall first shew you how to rectify the Globe for any Place; then, how to find the Place of the Sun, Moon, or Planet, in the Ecliptic for any given Time; and also, how to find the Time of their Rising, Southing, Setting, &c. for that Day; And lastly, I shall shew how, by the Stars on the Globe, you may find any Stars in the Heavens for any Time of the Year, and the Time of their Rising, Setting, &c.

Euphros. Well, this will be very delightful, and I promise myself a great deal of Pleasure and Advantage in such a Speculation. Therefore, to make a Beginning, pray tell me what you mean by *rectifying the Globe*?

Cleon. To rectify the Globe for any Place, is to *elevate the North Pole of it just so high above the artificial Horizon as the Pole-Star in the Heavens is above the natural Horizon of that Place.*

Euphros. How must I proceed to rectify the Globe for any particular Place, as *London*, for Instance?

Cleon. You must first learn the Latitude of the Place, either by Observation, or from some Table of the Latitudes. As that of *London* you'll find to be about $51^{\circ} 30'$, or this you may find on the *Terrestrial Globe*, by bringing *London* to the Brass Meridian, where you observe it passes under $51^{\circ} 30'$ of North Latitude. Having thus got the Latitude of the Place, take the Brass Meridian, and raise or depress it in the Frame, 'till the Horizon cuts it (on the North Part) in $51^{\circ} 30'$, equal to the Latitude of *London*, there let the Globe rest, and it will be

The CELESTIAL GLOBE.

Tab. XXXIV



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be the true Representation of the Position of the Earth and Horizon for *London*.

Euphros. Well, this I can do immediately.—The Globe is rectified.—What am I to do next?

Cleon. The next Thing is to find the *Sun's Place* in the Ecliptic for any given Time you please; this you are to do by the Calendar and Ecliptic on the Horizon; in the first of which you find the Day, and opposite thereto, in the latter, you find the Degree the Sun possesses that Day.

Euphros. Let me try if I can do this for the present Day, which is the 8th of *May*.—Let me see! Here I find the Day of the Month,—and then, in the Ecliptic, I find equal with it the 18th Degree of *Taurus*.—Is not that right?

Cleon. Very nearly; for in Instruments, however exact, we must not stand for a few Minutes, which make no sensible Alteration from what we behold in Nature.

Euphros. Well, as I have found the *Sun's Place*, what am I to do next?

Cleon. In the next Place, turn the Globe about 'till you see the same Degree of *Taurus* in the Ecliptic on the Globe, and thereon stick a small Patch, and bring that Patch to the *Meridian*, and let the Globe rest there.

Euphros. 'Tis done; the Patch is now under the *Meridian*: but, pray, *Cleonicus*, what does it represent there, the Sun?

Cleon. Yes, my *Euphrosyne*, it there represents the Noon-tide Sun for the present Day: For, as I have shewn you by the Orrery, whenever the Sun comes to the *Meridian* of any Place, it is then the Noon of that Day, or 12 o'Clock.—Therefore hold the Globe fast with one Hand, and with the other bring the *Hour-Hand*, or *Index* to the Hour XII, in the upper Part of the *Hour-Circle*, over the *Meridian*, and there let things remain.

Euphros. This I have done—what next?

Cleon. Now you may easily solve many very useful Problems in Astronomy; as (1.) The Globe, in this Position, shews you all the Stars and Constellations that were up, or above the Horizon, this Day at Noon. (2.) Observe the Degree the Patch touches upon the *Meridian*,
and

and that is the *Sun's Declination*. (3.) See what Degree of the Equinoctial is cut by the Meridian, and that will be the *Sun's right Ascension*. (4.) Turn the Globe *Eastward*, 'till the Patch touches the Horizon, which then represents the *Sun's Rising*, and the Index upon the Hour-Circle will shew the Hour. (5.) At the same Time, number the Degrees on the Horizon between the Patch, and the *East-point*, and that will be his *Amplitude of Rising* for this Day. (6.) Then turn the Globe *Westward*, 'till the Patch again touches the Horizon, and the Index will shew the *Hour of his Setting* this Day. (7.) You observe on the Horizon his *Amplitude of Setting* from the *West-point* towards the *South*. These Things you may practise first on the Globe, and then we will proceed to some other Problems.

Euphros. Well then, for the *Sun's Declination*, I see the Patch cuts the Meridian in or near the $17\frac{1}{2}$ Degree *Northward*, and that is his *Declination* for to Day.—Again, I observe the Meridian cuts the Equinoctial in about $45^{\circ} 30'$, which you say is the *Sun's right Ascension* this Day.—I have now brought the Patch to the *Eastern Side* of the Horizon, and I see the Index points to the Hour of VII: 30', for the *Time of his Rising*,—and his *Amplitude* is $27^{\circ} 20'$ to the South.—The Patch touches the *Western Side* of the Horizon, and the Index stands at the Hour of IV: 30', which is the Time the *Sun set* to Day,—and his *Amplitude of Setting* I see is the same with that of his *Rising*, viz. near $27^{\circ} 20'$ to the South.

Cleon. Very good, my *Euphrosyne*; no one could have solved these Problems on the Globe with more exactness than you have done.—Let us now remove the Patch, and put it on the first Degree of *Capricorn*, where the Sun is on the shortest Day of the Year, viz. the 22d of *December*, and we shall see that his *Rising*, *Setting*, *Length of Days and Nights*, &c. are the same as I shewed you by the Theory.

Euphros. Pray do;—I'll put it on the first Degree of *Capricorn*;—and now let me see,—the *Sun's Declination South* is then $23^{\circ} 30'$;—his *right Ascension* 270° ;—his *Altitude at Noon* 15° ;—the *Time of his Rising* is VIII: 13';—and of his *Setting* III: 47';—his *Amplitude* (now greatest)

greatest) Southward, is for his Rising and Setting, about 40° ;—which I see is almost *South-East*.——

Cleon. I find you are very ready at solving astronomical Problems;—and since on the shortest Day the Sun rises at VIII: 13', and sets at III: 47', 'tis evident, the Length of that Day is VII: 34', and of the Night XVI: 26', which is just the same as I told you from the Orrery.

Euphros. It is so; and I am pleased to see how exactly this noble Instrument corresponds with the Orrery, and common Observation; for I took notice this very Day, that the Sun went down by the Clock just at the Time shewn by the Globe.

Cleon. It did so; and had you observed it rising this Morning, you would have found it at the same Time, as by the Globe.—We have solved the *Phænomena* for the shortest Day; let us now suppose the Sun in the *Vernal Equinox*, that is, in the first Scruple of *Aries*, and see how these Things will fall out for that Time, which you remember is on the 21st of *March*.

Euphros. Very good, *Cleonicus*; it is a remarkable Season.—I think there needs no Patch to represent the Sun there; the Intersections of the Ecliptic and Equinoctial is a Point sufficiently notable without it.—I'll bring it to the Meridian, and—then I set the Hour Hand to XII, as before,—and thus the Globe now represents the Noon of that Day.

Cleon. Well, and how do you observe the foregoing Particulars on the Globe?

Euphros. I see they are very different from what they were before.—Now I observe the Sun's *Meridian, Altitude*, or Height at Noon; is $38^{\circ} 30'$, equal to that of the *Equinoctial*, the Sun being in it;—also, because the Sun is in the first minute of the *Equinoctial* as well as the *Ecliptic*, it has no *right Ascension*.—Also no *Declination*, for the same Reason.—Also, if I turn the Globe *East* or *West*, I see the Sun will rise and set just at 6 o'Clock; the *Equinoctial* being the Sun's Path for that Day—Again, I observe the Sun rises and sets exactly on the *East* and *West Points* of the Horizon; and therefore has no *Amplitude* that Day.

Cleon. You are very right in every Particular, my *Euphrosyne*; and thus you find the Days and Nights are then of equal Length, and all other Things happen just as they

they were explained to you by the Orrery. And in the same Manner, you'll observe Things to happen, if you suppose the Sun in the other *Equinox*, as on *September 23d*. Let us now proceed to the *longest Day*, viz. when the Sun enters into the first Degree of *Cancer*, and observe the State of Things for that Day, viz. the 22d of *June*.

Euphros. With a very good Will, *Cleonicus*; and on that Point I'll again stick on the solar Patch,—which I set to the Meridian, and the Hour-Index to the Hour of XII, for the Noon of that Day.—I now observe the Sun's *Meridian Altitude* is very great, being 62 Degrees,—and his *right Ascension* 90 Degrees;—his *Declination* is now $23^{\circ} 30'$ North, as it was before South on the shortest Day.—I see the Tropic of *Cancer* shews the Sun's diurnal Path for that Day, and by turning the Globe Eastward, when the Patch touches the Horizon; I see the Index stand at III : 47', the Hour of the Sun's *Rising* that Day.—And again, when I bring the Patch to the Western Horizon, the Index points to the VIII : 13', the Time of his *Setting* that Evening;—and his *Amplitude of Rising and Setting* is now just as much Northward, as it was Southward on the shortest Day.

Cleon. Very right, my *Euphrosyne*; and here again you observe also, that the Sun now rises on the same Hour in the Morning, as it set on the Evening of the shortest Day; and sets now at the Hour it did then rise: And moreover, that the Length of the Night now is equal to that of the Day then; and the longest Day now is equal to the then longest Night. All which you see is perfectly agreeable to the Theory. There are two or three Problems more worth knowing, relating to the Sun, to be resolved on the Globe by the *Quadrant of Altitude*, which you see is screwed on to the Meridian, at the Latitude of $51^{\circ} 30'$, viz. that of *London*.

Euphros. Pray what are they, and how resolved by that moveable Quadrant?

Cleon. One is, to find the Sun's *Altitude* any Hour of the Day, for any Part of the *Ecliptic*.—As suppose the Sun in the Beginning of *Cancer*, where the Patch now is, and I would know what Height the Sun is above the Horizon at Six o'Clock.—In order to this, I bring the Patch to the Meridian, and set the Index to XII, as usual;

then

then I turn the Globe till the Index points to the Hour of VI, where I hold it fast, and lay the Quadrant over the Patch, and by it I see the Sun is about 19 Degrees above the Horizon, which is his Altitude at Six, for the Morning and Evening of the longest Day.—Also, for the same Day, you find his *Altitude when he is due East or West*, thus;—I bring the Quadrant to the East Point of the Horizon, and turn the Globe till the Patch touches the Edge of the Quadrant,—which you see is at the 31° , and that is the Sun's Altitude when due East or West that Day.—Things remaining as they were, you observe the Time shewn by the Index, when the Sun is due East or West, viz. VII: 21' in the Morning; and in the same Manner, you will find it to be IV: 39' in the Afternoon.—And these Things you may find for any Day, while the sun is in the Summer Half of the Ecliptic.

Euphros. Yes, I imagine I can, *Cleonicus*;—the Method, by seeing you do it, seems pretty easy.—What other Problems remain?

Cleon. If by a common Quadrant, or otherwise, I take the Altitude of the Sun on any Day, I can find by the Globe what Time or Hour it was; thus—suppose on the 12th of May, in the Forenoon, I find the Sun's Altitude to be 46° , and would know the Time of Day,—I proceed thus: By the Calendar, I see the Sun's Place, on the 11th of May, is about $20^{\circ} 30'$ of 8; and there I stick the Patch on the Globe, which I bring to the Meridian, and set the Hour Hand to XII. Then I move the Globe and Quadrant so together, that I cause the Patch to touch the 46th Degree on the Quadrant, and then holding both still, I observe the Index points to IX: 30', and that was the Hour or Time when the Altitude was taken.

Euphros. This seems to be an useful Problem:—Which is next?

Cleon. By the Globe, you may find the Sun's *Azimuth* for any Hour of any given Day of the Year.—Thus, let us take the last Instance of May 11th, at Half an Hour after IX in the Morning; bringing the Sun's Place, $8 20^{\circ} 30'$, to the Meridian, and setting the Index to XII, I turn the Globe till the Index point to IX: 30', and there hold the Globe; then I lay the Quadrant over the

the Sun's Place, and it represents the Sun's Azimuth for that Time, *i. e.* it shews what Point of the Compass the Sun is upon; as in this Case it is upon the Point of (S. E. by E.) *South-East by East*; that is, 3 Points from the *East* towards the *South*. You are also to observe, that the Distance between the Quadrant and the North and South Part of the Meridian is called the Sun's *Azimuth from the North or South*; and is reckoned in Degrees on the Horizon. But as this Problem is chiefly of Use to *Navigators*, we will pass to another, which more generally concerns all Mankind, and is in itself very curious.

Euphros. What one is that, *Cleonicus*?

Cleon. Concerning the *Break of Day* and *Twilight*.—It is found by Observation, that after the Sun sets, 'tis not *dark Night* 'till he is descended about 18 Degrees below the Horizon; and when he comes to that Distance from the Horizon in the East, the *Day begins to dawn*.

Euphros. This I long to see you shew by the Globe; for that must be exceeding natural.

Cleon. And it will be the more so, by fixing this Brass-wire to the Horizon, encompassing the Globe at 18° below it; for this will represent the Boundary between *Twilight* and *dark Night*.—Cast your Eyes, therefore, below the Horizon, and you will observe, while the Globe is turned about, that the greatest Part of the *Ecliptic* will go below the Wire, and so will admit of *dark Night*; but some of the northern Part does not descend below the Wire, and therefore, while the Sun is in that Part, there will be no *dark Night*.

Euphros. Very good, *Cleonicus*; I apprehend you very well; but pray let me observe more nicely, how much of the *Ecliptic* is excused from that Boundary of *Darkness*.

Cleon. This you will best do, if I bring the Beginning of *Cancer* to the Meridian below the Horizon; and then you will easily see what Degree is cut off on each Side by the Wire.—I have set the Globe; you may make the Observation, as I turn it about.

Euphros. I will; I observe the *Ecliptic* first touches the Wire on the Meridian, in the 2d Degree of *Gemini* on one Side; and in the 28th Degree of *Cancer* on the other;—and I see by the Calendar, the Sun enters those Points on the 23d of *May*, and 22d of *July*; so that for the Space of 60 Days or two Months there is no *dark Night*.

Cleon. In the same Manner, if you regard any other Point in the Ecliptic, and stick a Patch on it; you will, by turning the Globe, easily see when it touches the Wire; and consequently, if you first bring the Patch to the Meridian, and then set the Index to XII, you may see what Time the Day dawns in the Morning, and the *Twilight* ends in the Evening of that Day the Sun is in that Part of the Ecliptic.

Euphros. Let me try this?—Suppose the Sun in the *Vernal Equinox*, on the 21st of *March*;—I bring that Point to the Meridian, and the Index to XII,—Now I turn it Eastwards till it touches the Wire,—when I observe the Index points to IV, the Hour when the Day begins to dawn.—Again, I turn it Westward till it touches the Wire, and the Index shews the Hour of VIII, for the Time when *Twilight* ends on that Day.—Well! this is a very pleasant Experiment, indeed!

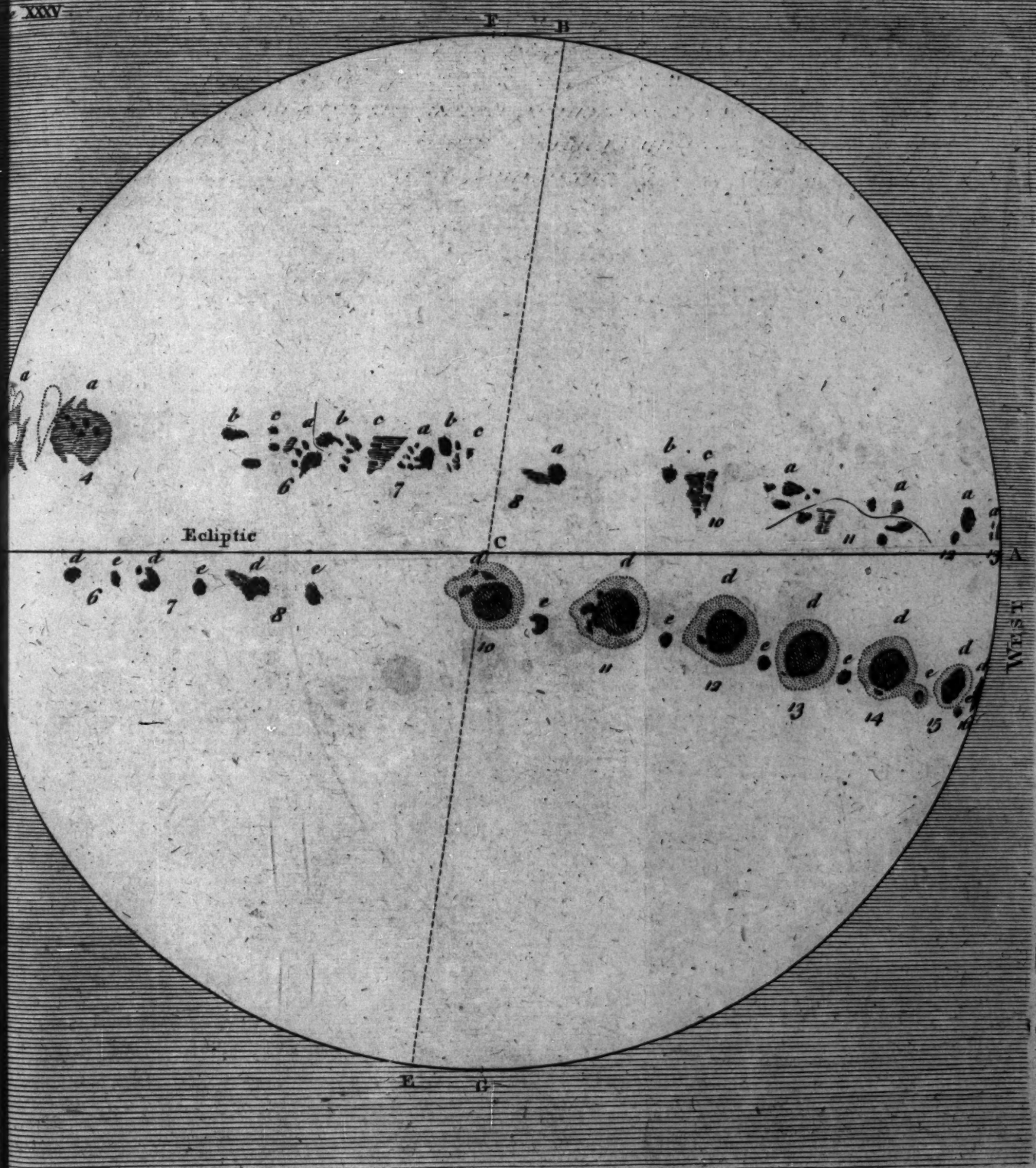
Cleon. The like you may do for any other Day:—I shall only observe to you, that since the Sun rises and sets on that Day at Six o'Clock, the Length of the *Twilight* is then just two Hours.—Thus you may find the Length of the same for any other Day, by subtracting from the Time the *Twilight* begins or ends, the Time of the Sun's Rising or setting that Day. —For Instance, let us take the 2d Day of *March*, when the Sun enters the 12th Degree of *Pisces*; and there putting the Patch, bring it to the Meridian, and set the Hour-Hand to XII; and then turning the Globe till the Patch touches the Wire, I observe the Index points to IV: 41' in the Morning for the Beginning, and to VII: 19' at Night for the End of *Twilight*. Now on that Day the Sun rises at VI: 38', and sets at V: 22', and the Difference of these Numbers from the former, is one Hour 57' for the Length of the *Twilight*; which you know is but little less than when the Sun is in the Equinoctial Point; and yet it is now the shortest of any in all the Year, except on the 12th of *October*, when it is exactly of the same Length.

Euphros. This is a very curious Point.—But, pray, how long is the *Twilight* on the shortest Day?

Cleon. You will find the *Twilight* on the 21st of *December* ends at V: 59', and the Sun then sets at III: 47';

therefore, the Length of Twilight must then be 2 Hours and 12'; which is 15' longer than in the last Case when least — And thus we have seen the Method of solving the *Problems relating to the SUN* on the CELESTIAL GLOBE. We will, the next Opportunity, proceed to the Problems of the MOON; which I dare say, you will think for the most Part very pleasant, and entertaining. But, in the mean Time, I shall make you a Present of a Map of the Solar Disk, or Face of the Sun, for the Sake of giving you a clear Idea of the Spots or *Maculae*, which so often appear in the Face of the Sun, and determine its Motion about its Axis; and though I have formerly shewn them to you through a Telescope, and you may have observed them several Times since; yet have you never so nicely observed their Motions, and the various Mutations, or Transformations they undergo, as to form a right Judgment of these curious Particulars. I have therefore selected out of 26 Periods of their Motions, observed and published by the accurate *Hewelius*, One, (*viz.* the 20th) which is the most elegant of all, and best adapted for your Purpose. You will there see the Course which is taken by two different Sets of *Maculae*, over the Face of the Sun; one of them below the Ecliptic DCA, and the other above it; both which you will easily observe, are oblique to the Ecliptic, and consequently, in their Motions describe Curves on the Sun's Face, somewhat like to the Parallels of Latitude, which you see on the terrestrial Maps, the Axis of which Motion is represented by the Line BCE, which is distant from the Axis or Poles of the Ecliptic FG, about $7\frac{1}{2}$ Degrees, as you see in the *Solar Map*. The Observation of these Spots was begun in the Year 1644, and continued from the 3d to the 16th of May. Below the Ecliptic, the Spots observed were two, represented by *d, e*, which were but just visible on the third Day, on the Eastern Limb, or Margin. — On the fourth Day, they appeared as at the Figure 4. — The fifth Day, they were not visible. — The sixth, seventh, and eighth Days, they were somewhat increased in Bulk. — The ninth Day, not visible. — The tenth, and following Days, the Spot *d* is vastly increased in Bulk, with an irregular Atmosphere about it, and a dark central Spot. — The other *Maculae e*,
continued

The COURSE of the Solar Maculae over the SUN'S DISK.



continued every Day much of the same Magnitude and Appearance; but on the fourteenth, it seemed to have a small Atmosphere, mingling with that of the large one. On the fifteenth and sixteenth, as they were so near the Western Limb of the Sun, their visible Magnitude lessened till they disappeared.—A great Variety of Transfigurations may be observed in the Spots marked *b, c, a,* in that Course above the Ecliptic, on the several Days of the Month there represented by Figures.

Euphros. I am obliged to you for this Piece of nice Instruction; I shall put it in a Frame with a Glass before it, that I may have this most wonderful and glorious *Phænomenon* always in my View.

DIALOGUE VI.

The Use of the CELESTIAL GLOBE in a Solution of LUNAR PROBLEMS, or those which relate to the Motion and Phænomena of the MOON.

Euphrosyne.

I Remember, when heretofore we talked of the Moon, you said her Path, or Tract in the Heavens, was not in the Ecliptic, nor was her Orbit constantly the same, but always varying; how then can you shew the Problems relating to the MOON on the GLOBE?

Cleon. The Task of investigating the Reason, or Cause of her various Motions, and framing a just Theory thereof, was, indeed, an arduous one; and reserved for the great genius of Sir *Isaac Newton*. But when once her Theory became established, it was easy to shew her Path, and her Place on the Globe, together with her *Nodes*, and their retrograde Motions, and the Solution of most other Problems of the Moon by a very simple and easy Contrivance, as an *Appendage* to the Globe.

Euphros. Indeed! Pray, what and how is that? I long to know.—

Cleon. It is no more than a piece of Silk Twist, with its two Ends so tied together, that, when put on the

Globe, it shall girt it very tight.—This is the Thing,—and when I put it upon the Globe, it will there represent the Moon's Way.

Euphros. But since the Moon's Orbit lies across the Ecliptic, how can you tell where, and how to fix it?

Cleon. By an *Ephemeris*, (as *Parker's*, *Weaver's*, &c.) I can easily find the *Place of the Nodes*, or Points of the Ecliptic, in which the Moon's Orbit crosses it, for any given Time of the Year. By the same *Ephemeris*, I also find the Latitude, or Angle which the Moon's Orbit makes with the Ecliptic for that Time; but this on the Globe may always be taken about $5\frac{1}{4}$ Degrees, without any sensible Error.

Euphros. Well then, since it is so easy a Thing, pray, *Cleonicus*, put on the Silk Cord to represent the Orbit of the Moon, for the 14th Day of *August*, 1759.

Cleon. I will—here is *Parker's Ephemeris* for 1759, in which the Moon's Place and Latitude is shewn for every Day of the Month at Noon, and the Place of her Nodes for every sixth Day, as you see in those Columns respectively.—Thus, on the 14th Day of *August*, the Moon's Place is in *Taurus* $8^{\circ} 10' 13''$,—her Latitude is $4^{\circ} 14'$, and her ascending Node ☊ in $5^{\circ} 4\frac{1}{2}'$ of *Cancer* ☋, and the descending Node ☋ is of Course in the opposite Sign *Capricorn* ♑,—therefore I put on the Silk Line upon the Globe, in such a Manner as that it may intersect the Ecliptic in those two Points.—Lastly, at the Distance of 90 Degrees on each Side the Node, I raise the String on one Side, and depress it on the other, till it is $5\frac{1}{4}$ Degrees distant from the Ecliptic.—Thus, you see, the silken Path of the Moon represented for the 14th Day of *August*.

Euphros. I do, and with great Satisfaction, as it gives me the clearest Idea of the different Paths of the Sun and Moon through the Heavens. But since this is the Case, how is it, that the Moon is said in the *Ephemeris* to be in such a Degree of such a Sign of the Ecliptic?

Cleon. This you must understand is her Place, reduced from her Orbit to the Ecliptic, by a Line conceived to pass through her Center to the Ecliptic, which is called a Circle of Latitude; and this is done by the *Ephemeris-Makers* for every Day in the Year.—Thus, for Instance, the said Circle of Latitude passing through $10^{\circ} 13'$ of *Taurus*

Taurus 8, will cut the Silken String in a Point, which will shew the true Place of the Moon in her Orbit for that Day at Noon.

Euphros. I understand you perfectly well; and so, I suppose, if I stick a Patch upon that Point, it will be a true Representation of the Moon's Place, in order for the Solution of such Problems as relate to her Rising, Setting, &c. for that Day.—And therefore—

Cleon. But hold, Sister, one Thing you seem not to recollect, which is the large Space which the Moon describes every Day in her Orbit, by which Means it becomes necessary to find her Place, not for the Noon of the Day, but for any Number of Hours, before or after, at which her Appearance is required.—Thus, for Instance, supposing the Time of her Rising on that Day was required, her Place must be sought for about six Hours before Noon; and for the Time of her Setting, her Place must be sought for six Hours after.

Euphros. You do well to put me in mind of so necessary a Point.—I well remember, you shewed me, on the Orrery, that the daily Motion of the Moon was about 13 Degrees at a Mean, but in the *Ephemeris* for the proposed Time, I observe, that the Motion of the Moon, from the Noon of the 14th, to that of the 15th, is $14^{\circ} 6'$. Therefore about a fourth Part of that Space, viz. $3^{\circ} 16'$, must be added to her Place, the 14th Day at Noon, for her Place at Six in the Evening, which will make $13^{\circ} 29'$ of *Taurus* 8, where, I suppose, I may now stick the Crescent-Patch.

Cleon. That will be the Place of the Moon for the Evening of that Day, and by Means of the Crescent, which you have placed under her Orbit, just below that Point of the Ecliptic, you will find her Phænomena for that Evening, much after the same Manner you did those of the Sun, in regard to its Rising, Setting, South-ing, &c.

Euphros. So I apprehend:—But let me try how ready I am at the Practice.—The first Thing I have to do, I suppose, is to rectify the Globe to the Latitude of the Place,—and then to bring the Moon's Place to the Meridian.—

Cleon. By no Means, Sister,—It is the Sun's Place you are to bring to the Meridian, and place the Hour Index at XII, and thus it will be rectified for your Purpose.

Euphros. If I knew how to do the Thing, I should not need a Tutor.—But I see the Reason of it at once, now you have set me right.—Well! let me proceed.—The Sun's Place I find in the *Ephemeris* for that Day at Noon is $21^{\circ} 16'$ of *Leo*, which Point of the Ecliptic I bring to the Meridian, and there holding it fast, I fix the Hour-Hand to XII, and thus it is rectified for that Day: Then I turn the Globe, 'till the Index points to the Hour of VI.—But I see no Moon above the Horizon.—Of Course, I turn the Globe 'till the Crescent comes into the Eastern Part of the Horizon, where it shews the Moon rising at a few Minutes after X, upon the E. N. E. Point of the Compass nearly, and about 21 Degrees of Amplitude North.—Am I not so far right, *Cleonicus*?

Cleon. You are very near the Matter:—But if you would be very exact, you must make still more Allowance for the Moon's Motion for 10 Hours, instead of six, which will carry her a little farther Eastward, and make her rise somewhat later.——

Euphros. I see the Necessity of it, from what you have said, and I was going to say, that I had nothing now to do but to bring the Crescent to the Meridian; but I observe, that will take up 7 Hours Motion of the Globe, which added to the former 10, makes 17 Hours, from the Noon of the former Day; therefore $\frac{1}{2}$ of the Moon's daily Motion, or near 10 Degrees, must be added to her Place the foregoing Day, which will give the 20th Degree of *Taurus* 8, in the Ecliptic, for the Moon's Place in her Orbit just below, to which I must now remove the Crescent; and having brought it under the Meridian, I see the Hour-Index points to about Half an Hour after Five, for the Time of her Southing, on the 15th Day; and this, I observe, is confirmed by the Time of the Moon's Southing in the common Almanac, prefixed to *Parker's Ephemeris*.—Then next, I observe, that in bringing the Crescent to the Western Horizon, there will be about $7\frac{1}{2}$ Hours Motion of the Globe required, which must likewise be allowed for in the Motion of the Moon, which,
added

added to the former, make out the Motion of the whole Day, or 14 Degrees.—And thus I find the Time of her Setting to be about One o'Clock on the 15th Day.—Hence also it appears by the by, that on the Day before, or 14th Day, the Time of her Setting was about Mid-day.

Cleon. I am glad to see you are so dextrous, my *Euphrosyne*, at the Solution of Lunar Problems; and though they are not so readily performed as those of the Sun, yet are they, in their own Nature, more curious, and very easy, with a little Practice, by Means of the *Ephemeris*, and the most difficult Part is now over. In the Solution of these Sort of Problems, there is also greater Variety than in those of the Sun; for here we may observe, that as the Moon's Orbit makes an Angle with the Ecliptic, we enquire for the Latitude as well as the Longitude of the Moon, and you observe, in the *Ephemeris*, that her Latitude, on the 14th Day of August, at 12 o'Clock, is $4^{\circ} 14'$.—

Euphros. Very good; I see it is; but what are those numerous Lines crossing the Ecliptic at right Angles all around the Globe, and others that run parallel to the Number of 8 on either Side, and what is their Use?

Cleon. They are called by Astronomers the *Zodiac*, and they are drawn at the Distance of a Degree from each other, and those which are perpendicular to the Ecliptic serve to measure the Degrees of Latitude in the Moon and Planets, none of which ever deviate so far as 8 Degrees from the Ecliptic; and therefore, wherever the Places of these celestial Bodies are found, their Latitudes from the Ecliptic are by these Lines easily shewn; as also the Longitude, and many other valuable Uses are to be made of them, as we shall find in our future Practice. This *Zodiac* is one of the many great Inventions of the late Dr. *Halley*, and has, about 20 Years since, been placed upon Mr. *Senex's* celestial Globe, for rendering its Use more extensive and perfect.

Euphros. This must be a very great Improvement of the Globe, as I myself am Witness; since, by those Lines, I see the same Latitude of the Moon expressed on the Globe, as I do in the *Ephemeris*; whereas, with-

out those auxiliary Lines, I could not have known what her Latitude had been, without the Trouble of measuring it by the Degrees on a Quadrant of Altitude.

—I likewise see, at the same Time, what Latitudes correspond to the Place of the Moon in every Part of her Orbit, or Distance from her Node, which must be a very great Satisfaction and Pleasure to all Lovers of Astronomy.

Cleon. By Means of the silken String, you will be enabled, at all Times, to observe the Declination of the Moon from the Equinoctial Line, which will be sometimes less than that of the Sun; and be sometimes North, when that of the Sun is South, and *vice versâ*.

Euphros. Well! let me enquire what the Declination of the Moon is for the 14th Day of *August* at Noon. —I bring the Crescent to the Meridian, and there find it under $11^{\circ} 40'$, which therefore is the Declination for that Time. —Indeed, by this artificial Lunar Orbit, I can easily see, that the Declination of the Moon may be sometimes five Degrees greater, and sometimes so many Degrees less than that of the Sun. —I also see, that her Declination may be North, while her Latitude is South, and the contrary; —and were the Lunar Orbit to intersect the Ecliptic in the Equinoctial Points, it would cause the Moon to appear much nearer our Zenith, at some Times, than ever the Sun has been seen; and to shew her but at a small Distance above the Horizon at other Times: —And such Appearances of the Moon I have really seen, and wondered, at the same Time, how it came to be so; nor do I yet see the Reason plainly, unless I can suppose the Nodes of the Moon's Orbit to change their Places, and at Times get into the Equinoxes.

Cleon. You have now hit upon the very Thing that causes such a pleasing and wonderful Variety in the Lunar Phænomena. —The Nodes of the Lunar Orbit are not fixed, but constantly in Motion in a *retrograde* Manner; *i. e.* they go backward, or contrary to the Order of the Signs, and at such a Rate, as to be every Year 20 Degrees more backward in the Ecliptic than before. This you may be easily convinced of by the *Ephemeris*; for the Place of the ascending Node for the first

first Day of *January*, for the present Year (1758), was in $15^{\circ} 51'$ of *Cancer*, and through every Month of the Year it retrogrades, till the last Day of *December*, it is found in $27^{\circ} 30'$ of *Gemini*; and thus, in the Space of about $18\frac{1}{2}$ Years, the Nodes go backward through all the Points of the Ecliptic, and consequently, once in that Time the ascending Node will be in the Beginning of *Aries*, and shew the Moon nearer to, or farther from our *Zenith*, by 5 Degrees, than ever the Sun appears; but, when it possesses the autumnal *Equinox*, the contrary will happen; and there are few People that live to the Age of 30 or 40 Years, but what must remember to have seen this Variety of Lunar Altitudes, as they happen so remarkably different, in the Space of little more than nine Years.

Euphros. I shall not trouble you with it now, *Cleonicus*, but, for my own Amusement at leisure Hours, I shall put this Lunar Orbit into all its different Positions, with regard to the Ecliptic, to see from thence all the Variety of Appearance that can arise, with regard to her Altitudes, Rising, Setting, &c.

Cleon. Now you talk of her Rising and Setting, I must observe to you, that there will be something peculiarly strange and entertaining result from your Experiments of that Kind; especially, if you enquire how these Phænomena will be circumstanced, in regard to the different Parts of the Earth, by rectifying the Globe to many different and extreme Degrees of Latitude. — One Phænomenon of this Kind you have heard much talk of, usually called the *Harvest-Moon*, and sometimes the *Shepherds*, and the *Hunters-Moon*; which, if you remember, I told you I should reserve for an Explication, 'till I came to the Use of the celestial Globe; this being the only Instrument by which it can be naturally represented and clearly understood.

Euphros. Nothing will be more grateful to me than the Explanation of a Phænomenon I have so long desired to understand, and which is looked upon almost as a Prodigy among Country People.

Cleon. As much as this has amused and surpris'd many People, and as prolix and tedious as some Discourses have been to explain it, you will find that there is nothing strange

strange or wonderful in the Nature of the Thing itself, and that it requires but very few Words to explain it, at least to the Apprehension of the Fair Sex.——For this Purpose, take your Globe, and rectify it for the Latitude of *England*, and turn it about, 'till the two equinoctial Points are in the Horizon, the Vernal *Equinox* in the Western Part, and the Autumnal *Equinox* in the East.

Euphros. This I have done;——and what follows then?

Cleom. You will then observe, that the Ecliptic has a great Elevation above, or makes a very large Angle with the southern Part of the Horizon, viz. about 62 Degrees. Now turn the Globe about, so that the *Equinoctial* Points may interchangeably possess the same Parts of the Horizon as before, i. e. the Autumnal *Equinox* in the Western Point, and the Vernal *Equinox* in the Eastern Point.

Euphros. This is easily done;——and I guess what you have next to tell me.——Is it not to observe how small the Angle is which the Ecliptic now makes with the Horizon?

Cleom. That is the very Thing my *Euphrosyne*; for on these two different Positions of the Ecliptic, with respect to the Horizon, the whole Affair depends, which we shall render more easily to be understood, by exemplifying this Matter in the following Manner.—In the first Case, suppose there was a full Moon on the Day of the Vernal *Equinox*,—then I bring the first Degree of *Aries* to the Meridian, and set the Hour Index at XII.—I turn the Globe, 'till that Point touches the Horizon, and shews the Sun Setting therein;—then you will easily understand, that the Full Moon is in the first Point of *Libra*, and rising in the Eastern Point of the Horizon, and just at Six o'Clock.

Euphros. All this I perceive very plainly. What am I to observe next?

Cleom. You will now recollect, that since the Moon moves in one Day about 13° , therefore the next Day at Night, at Six in the Evening, the Moon will be advanced to 13° of *Libra*; and therefore, to shew her Rising in the Horizon, the Globe must be turned about, 'till that Degree of *Libra* appears in the Horizon;——

then

then look at the Hour-Index, and you will see it point to 16 Minutes past VII.—Whence you observe, the Time of her Rising is one Hour and a Quarter later than on the Equinoctial Day, or Evening before.

Euphros. All this is very easy; and I presume you are next to shew the same Thing, or the Difference in the Time of her Rising for the other Equinoctial Day.

Cleen. You rightly judge of my intention.—I bring the Point of *Libra*, which the Sun is now supposed to possess, and place the Index to the Hour of XII.—Then turning the Globe, I bring that Point to the Western Point of the Horizon, to shew the Sun there setting, with the Index pointing to VI.—Then in the Eastern Point of the Horizon, the Moon is rising, at the same Time, in the first Point of *Aries*.—Then, since the Moon will, by Six o'Clock the next Evening, have advanced 13° forward, I must turn the Globe, till the 13° of *Aries* rises;—and I turn it, you see, but a very little before the Moon appears; for look at the Index, and you will see it point out the Time of her Rising, which is but about 22 Minutes after VI.

Euphros. The whole Thing is now unravelled—By this Experiment, I at once see the Nature of this Phenomenon.—The small Angle which the Ecliptic now makes with the Horizon, is the Reason why so small a Motion of the Globe is necessary to make the Moon rise after the setting Sun.—But 22 Minutes Difference in Time now, and 76 in the former Case.—Hence it is very evident, that for several Nights about the Autumnal Equinox, we are no sooner bereft of the Sun-Beams, but the Moon illumines the sky with her silver Light.—The contrary of all which must happen at the Vernal Equinox, where so large a Space must intervene between the Setting of one Luminary, and the Rising of the other; and consequently, I am fully satisfied from hence, why those lightsome, pleasant Evenings should occasion the forementioned Appellations of the Moon, as being so particularly serviceable to Shepherds, Sportsmen, and People in the Harvest-Field.—And I farther observe, that this small Difference of Time between the Setting of the Sun and the Rising of the Moon, in the autumnal Season, will be still farther lessened, when the Nodes of the Moon

are

are in the Equinoctial Points, *i. e.* when the ascending Node possesses the first Point of *Aries*; for then the Moon's Orbit will be most oblique to the Horizon, or make the least Angle with it.

Cleon. Your Readiness in apprehending the Reason of these Phenomena, supercedes the Necessity of insisting any longer upon this Subject.

Your next Exercise will be the Planetary Praxis, which will afford you such Instruction, as will be attended with equal Pleasure and Use, and be a convincing Proof, how necessary a Part the celestial Globe must be of an Apparatus for the Education of young Gentlemen and Ladies.

DIALOGUE VII.

The Use of the CELESTIAL GLOBE, in the Solution of PROBLEMS relating to the PLANETS and COMETS, exemplified in that which lately appeared.

Cleonicus.

THE present Hour, my *Euphrosyne*, is destined for your farther Instruction in the Doctrine of practical Astronomy. You know full well how useful the Celestial Globe is, in the Resolution of such Problems as relate to the Sun and Moon; and you will now find it very easy to apply that excellent Instrument, in the same Manner, to solve all such Questions as relate to the Planets and Comets.

Euphros. I make no Doubt but I shall; and it is a particular Pleasure to find, that Problems of so sublime a Nature, admit of a Solution with such great Facility by the Globe. The happiest Invention sure that ever Mankind was blest with! And it is no Wonder, when we see those noble Instruments in the Study of every Gentleman and Lady of Taste.—With regard to the Planets, I presume, there will be no great Difficulty; but how you are to inculcate the Use of the Globe for the Comets, I am quite at a Loss to guess, as I have scarcely ever heard such a Thing, or ever find the Mention of it in those

Authors

Authors you have recommended me to read upon the Subject.

Cleon. Never fear, my *Euphrosyne*, though the Subject be new, it is not difficult; and you may have the Pleasure of being the first of your Sex, to enjoy the Benefits of the Praxis on Cometary Astronomy. The Comets are, properly speaking, no other than a very large and numerous Class of Planets, whose Motions, performed in the Heavens, I have already explained to you; and it is the Glory of the present Age to have the first and fullest Confirmation of this new Species of Astronomy confirmed, as we may say, by Experiment. I mean, by the return of that Comet, which I formerly told you was expected, and which, during the Month of *May* last (1758), made its Appearance above our Horizon, according to the Time calculated, and predicted by the late great Dr. HALLEY.

Euphros. The Novelty, as well as the Usefulness of such a Subject, must give the highest Pleasure to every young Tyro in Astronomy.—The Return of a Comet has a Sound, great as the Event itself; and if I can be so happy as to understand by the Globe the several Appearances of such a wonderful Phænomenon, in its Passage through the visible Part of our System, it will be the Completion of my highest Expectations.—But, I suppose you will begin with the Planets first.

Cleon. Yes; but that will prove a short and easy Task, as you have been already instructed in the Manner of finding the Places of the Planets for any given Day in the *Ephemeris*; and likewise, at the same Time, the Manner of finding their Places in the Heavens, by an artificial *Planetarium**, and their Positions and Aspects with respect to each other. The Use of the Globe for this Purpose is only for the Sake of Variety, and shewing the same Things, if possible, in a more natural and easy Manner.—The first Thing, therefore, that I shall enjoin you is, to take your Paper and Patches and your *Ephemeris*, and lay them before you on the Table by the Globe.—Then find each Planet's Place separately.

* See Dial. XIII. p. 85, 86, 87, of Vol. I. Part I.

rately, for the first Day of *October* next.—Then stick a Patch on each Planet's Place in the Ecliptic, denoting the Size of the Planets.—And, lastly, rectify the Globe for the Hour of X, in the Evening of the afore-said Day.

Euphros. This Problem, I see, consists of four Parts, to each of which I shall readily address myself.—Here are the Patches, in the first Place;—and here also the Part of the *Ephemeris*.—Now, let me see for *October*, the 1st Day; I observe, in the Column of *Saturn* Retrograde (R). I find his Place is $10^{\circ} 36'$ of *Pisces* ($\times$).—This Place I find in the Ecliptic on the Globe, and there I stick a large Patch.—So far I am right, with regard to this Planet, *Cleonicus*.

Cleon. I see you are extremely ready at finding the Planets Places. You want none of my Instructions, but may proceed in the same manner to find the Places of all the rest on the Globe.

Euphros. In the next Column, I find *Jupiter* ♃ possesses $13^{\circ} 38'$ of *Capricorn* ♑, and because he is the largest Planet, I shall put a Patch of the largest Size on that Point of the Ecliptic on the Globe.—In the following Column, I find *Mars* ♂ in $9^{\circ} 29'$ of *Leo*; in which Part of the Ecliptic on the Globe I stick a smaller Patch.—In the next Place, *Venus* ♀ I observe, in $12^{\circ} 31'$ of *Scorpio*; where I shall place a Patch one Size larger.—And lastly, the little puny Planet *Mercury* ☿, is just entered the 22° of *Virgo*. On the first Minute of that Sign, therefore, I place the smallest Patch; and thus, I think, *Cleonicus*, we have brought down all the Planets from the Heavens, and consigned them to their proper Places on the Surface of the celestial Globe, for the Time appointed.

Cleon. You have performed this Part very accurately indeed.—Your next Business now is to rectify the Globe for the given Day.

Euphros. This I can soon do.—I elevate the North Pole to $51^{\circ} \frac{1}{2}$ —in the first Column for *October*, against the 1st Day, I see the Sun's Place in $7^{\circ} 58'$ of *Libra*, on which Point of the Ecliptic I stick a round Piece of red Paper, to denote the Sun, and bring it to the Meridian, placing at the same Time the Index

to the Hour of XII,—and thus the Globe is rectified as you require.

Cleon. It is so.—And now nothing remains but to turn it round, till the Index points to the Hour of X at Night, and then you will see which Planets are visible above the Horizon, and which are not; also the Time when they rise, culminate, set, &c. when they may be seen with a Telescope, and when not; with many other useful Particulars.

Euphros. That is done.—And now I observe the largest Patch at the western Part of the Horizon, which shews *Jupiter* near setting at that time.—The next larger Patch, I see, is a little on the East-side of the Meridian; by which I am informed, that the Planet *Saturn* is, at that Hour of the Night, nearly South; but as for the rest of the Patches, I see none above the Horizon, by which I am satisfied they are all invisible below for that Time of the Night.—I learn from hence, that *Saturn* then is in the best Situation to be observed by the Telescope; and that *Jupiter* will be too low in the Atmosphere, and too near the Horizon to be well observed, even at 9 o'Clock.—I move the Globe to bring *Jupiter* on the Meridian, and it shews him full South, at Half an Hour after VI, on that Day; at VII nearly, I see the Planet *Venus* setting,—and the Planet *Mercury* rising at Half an Hour after XII.—The Planet *Mercury* rises about V, a little before the Sun.—And thus I am instantly satisfied of the Appearance of those Planets for that particular Time; and can easily find them for any other.—What is there farther to be done in the planetary Praxis?

Cleon. Nothing material. One Thing only may be observed, that their Orbits do not coincide with the *Ecliptic*; yet, as they deviate to such small Distances from it, it is not worth while to consider it in Practice, as it makes no sensible Difference on the Globe*.——We therefore

* But lest any of our Readers should have the Curiosity of performing these Problems according to the precise Truth, and would chuse to represent their Orbits by a silken String, or Thread, as was directed in the Case of the Moon; it will be necessary

therefore next proceed to the Comet, and your Business now will be to learn how you trace the Course of a Comet through the Heavens, on the Surface of a celestial Globe, and to shew the same, during the whole Time of its Appearance. Of this you will have an Example, sufficiently noble and instructive, in the Comet which lately made its Appearance. — This Comet was seen at *Boston* in *New-England*, in the Months of *October* and *November*, 1758, in its Return to the Sun, when the Orbit of the Comet was but a small Distance from that of the Earth, in the Part where they observed it; after which, it approached so near the Sun, as to be lost in its Beams for some Time, 'till after passing the *Perihelion*, it became again visible in its *retrograde* Course from the Sun, towards the latter End of *March*; when it was seen, and observed by many Gentlemen in the *West-Indies*, and particularly by Mr. *Brown* at *Jamaica*, it was observed, during the whole Month of *April*, and Part of *May*, whose Latitude rendered it visible to him, while it was for the greatest Part of the Time invisible to us, by reason of its southern Course through the Heavens. This Gentleman has given us an Observation on the Comet, on the 31st of *March*, by which you will easily find its Place in the Heavens, on the Surface of the celestial Globe. — But first, you must rectify the Globe for the Latitude of *Jamaica*, which is $17^{\circ} 30'$, as you will hereafter see on the terrestrial Globe.

necessary to give here the Place of the Nodes, and Inclination of the Orbit for each particular Planet for the present Time as below.

The Place of the Node of the Or- bit of	Mercury	_____	8	8	6
	Venus	_____	11	15	2
	Mars	_____	8	14	26
	Jupiter	_____	26	18	30
	Saturn	_____	26	7	20
The inclination of the Orbits of	Mercury	_____	_____	6	54
	Venus	_____	_____	3	24
	Mars	_____	_____	1	52
	Jupiter	_____	_____	1	20
	Saturn	_____	_____	2	30

Euphros. As you give me the Latitude, I can as well rectify the Globe for the Latitude of *Jamaica* as for that of *England*.—Therefore I bring $17^{\circ} 30'$ to the Horizon, which shews the Elevation of the Pole for that Place.—Then on the 31st of *March*, I see the Sun's Place is in $10^{\circ} 29'$ of *Aries* γ , which, therefore, I bring to the Meridian, and fix the Index to XII.—Thus it is rectified for the Noon of that Day.—What is to be done next, *Cleonicus*?

Cleon. At Five in the Morning, that Gentleman observed the Comet's Altitude was $22^{\circ} 50'$, and its Azimuth 71° S. E.—By this, you will readily enough find its Place on the Globe, from what you have already learned.

Euphros. I believe I shall be able to assign its Place with a little Recollection.—The Time was Five in the Morning; therefore, I must turn the Globe about, 'till the Index points to the Hour of V.—In the next Place, the Comet's Azimuth, it seems, was 71° from the South towards the East.—This requires the Quadrant of the Altitude to be fixed in the Zenith,—which I have done.—Then I bring the said Quadrant to cut the Horizon in 71° from the South Point;—and lastly, since the Altitude of the Comet was then $22^{\circ} 50'$, under that Point in the Quadrant will be the Comet's Place, where of Course I must stick a Patch to represent it:—And I think I am so far right.

Cleon. You are, my *Euphrosyne*, right in every Particular but one.—Your Comet has got no Tail; but that we shall dispense with for the present.—You have justly assigned its Place for that Time, which you will observe to be in the *Zodiac*, with about 3° N. Latitude from the *Ecliptic*, and in about the 27° of *Aquarius*.—Now, shew me the Time that it rose in the Horizon of *Great Britain*, on the abovementioned Day.

Euphros. That I shall instantly do.—The Globe is now elevated for the City of *London*.—I next bring the Comet to the western Part of the Horizon, and find it there between Two and Three o'Clock in the Afternoon; therefore it could not be seen in the Evening.—Next, I bring it to the eastern Horizon, and then observe, the Index points to $45'$ after III.—This, therefore, was the Time of its Rising that Day.—But, pray, how came

the *British* Astronomers not to observe it, or mention its being seen at that Time in *England*?

Cleon. This I cannot easily account for, unless it was, because the Sun was near the Horizon, and caused a Twilight, or Dawn, too strong for it to be observed; as likewise, the Vapours of the Atmosphere might be another Reason for rendering it incapable of being seen; but it was quite otherwise in the Latitude of *Jamaica*, where the Comet was high, the Sun much below the Horizon, and the Morning Dark at the Time of observing it.—You have thus found one Place of the Comet, and by finding one other, you will be able to represent the Tract which is described in the Heavens between both.

Euphros. For that Purpose, I suppose, it will be necessary, that you mention the like Observation made on the Comet at some other Time, and Place.

Cleon. That is a Point certainly necessary, and I shall give you my own Observations for that Purpose, which were accurately made the 6th Day of *May*, at Ten in the Evening, by measuring its Distance from two Stars in the Back of *Hydra*, which you see marked with the two *Greek* Letters μ and ν , and by an Azimuth Quadrant, its Altitude was found about 16° , and its Azimuth 37° S. W. from whence you will easily find its Place on the Globe, as in the foregoing Case.

Euphros. I shall immediately set about it.—I elevate the Pole to the Latitude of *London*.—The Sun's Place, on the 6th of *May*, is $15^{\circ} 35'$, which I bring to the Meridian, and set the Index to XII.—Then I revolve the Globe, 'till the Index points to X at Night.—The Quadrant of Altitude being fixed for the Zenith, I bring it to the 37° in the Horizon, from the South towards the West.—And, lastly, under the 16° , on the Edge of the Quadrant, I put a small Patch, which must, I presume, represent the Place of the Comet where you saw it.

Cleon. It will so, as nearly as any Thing can be done on the Globe:—And you observe the Patch is but a little above the two Stars just now mentioned.

Euphros. I see it very plainly: But how am I to draw the Path of the Comet after all this?

Cleon. You must know, that the apparent * *Path* of the *Comet* through the Heavens is pretty nearly a great Circle of the Sphere; and therefore, as you have two places of the *Comet* represented on the Globe, by the two Patches, if you bring the Centers of both those Patches nicely into the Horizon, you may, with a Pencil, draw a Line from one Patch to the other by the Horizon, and that will tolerably well represent the apparent *Place* of the *Comet*, from one Time to the other; that is, from the 31st of *March* to the 6th of *May*.

Euphros. This I will endeavour to do:—By raising and depressing the Pole, and adjusting the Patches towards the Horizon, I find the Problem not very difficult.—— I have, at length, brought them nicely to coincide; one in the eastern and the other in the western Part of the Horizon——From the eastern Patch, I draw a Line by the Frame of the Horizon to the western Patch, and it shews a vast Tract of the Heavens, through which the *Comet* passed in so short a Time, viz. more than 150° , which shews the *Motion* of the *Comet* to have been very quick; and I observe, it passed through the following Constellations in its Way, viz. by the *Tail* of *Capricorn*, the *Tail* of *Piscis Australis*, by the *Head* of *Indus*, the *Neck* and *Body* of *Pavo*, through the *Neck* of *Apus*, below *Triangulum Australe*, above *Musca*, by the Lowermost of the *Crossers*, a-cross the *Hind Legs* and through the *Tail* of *Centaurus*; from thence between the two Stars in the *Back* of the *Hydra* before mentioned; after this, it passed on to *Sextans Urania*, and then to the *Ecliptic*, near *Cor Leonis*, after which, you can better tell what became of it than myself.

Cleon. Your Performance is excellently good, my *Euphrosyne*.——Through those very Constellations, Mr. *Brown* observed it to pass from Day to Day, during the Month of *April*, as appears by his Letter, containing the Observations which he made, and are now published for the Satisfaction of the curious,†,——You will easily

* See the *Print* of the *Comet's Path*, taken from the Globe, in the *Magazine* for the Month of *May*, 1758.

† See the Beginning of the *Miscellany* for the last Month.

observe from the Whole, that the South Latitude of the *Comet* being so very great, appears now to be the Reason why we in *England* could not see it in that Month; and that it was just about the Beginning of *May*, when it emerged again above our Horizon; after which it regaled our Eyes with a faint Appearance, 'till towards the latter End of that Month, and gradually disappeared by its distant Recess.——Thus much will be sufficient for giving you an Idea of the Manner, in which the various *Phænomena* of *Comets* may at any Time be represented on the Globe: Besides which, and the *Cometarium* heretofore described, you may still receive a much clearer Insight into the *Nature* and *Motions* of a *Comet*, by consulting the several Prints which have been published, with regard to the present *Comet*, and particularly that, in which the *Orbit* of the said *Comet* is elevated, and its daily Motion marked out, together with the *Ecliptic*, divided into all the Months and Days of the Year, which now you are very well qualified thoroughly to understand*. There is yet a farther Use of the celestial Globe, that will afford you some Amusement; at least it will be necessary, that a young Lady of your Taste should not be unacquainted with it; I mean, the Solution of those Problems, which relate to the Stars, which I intend for the Improvement of the next Opportunity.

DIALOGUE VIII.

The Use of the CELESTIAL GLOBE, in the SOLUTION of PROBLEMS relative to the STARS.

Euphrosyne.

I Cannot help thinking, whenever I cast my Eye on the Celestial Globe, but that it is an amazing Effect of Art. He must have had a very happy Thought, who could

* *The Prints, here referred to, are a VIEW of the SOLAR SYSTEM and ORBIT of the COMET; with its proper Elevation, truly representing all its Appearances for any Part of the Year.*

The

could first contrive to represent, in so natural a Manner, the vast expanded Canopy of the Heavens, with all its resplendent Furniture, in so small a Compass as the Superficies of an artificial Globe. I have but one Objection, or rather, but one Thing to remark, and that is concerning the Form of the Globe. The Surface of the Globe is *convex*; and that of the Heavens *concave*; how then can one be an adequate Representation of the other?

Cleon. This is very ingeniously observed, my *Euphrosyne*; but you will see the Answer is very easy. There is no Difference, in Reality, between the convex and the concave Surface, any more than what the *Metaphysicians* call *Modal*, and only exists in the *Form*; the optical Effect of viewing any Thing, upon a convex or concave Surface, is the same to an Eye, placed in the Center thereof: Suppose, for Instance, you had a Sphere of Glafs, and your Eye was placed in the Center, it would be the same Thing, if the Stars were marked with a Diamond on the external or internal Part of the Surface, *i. e.* on the convex or on the concave Side; and it is the same Thing, in regard to the artificial Globe, to an Eye on the Outside of it. For, if that Globe was to have Holes pierced through the several Stars, and the Globe properly rectified for a given Time, an Eye, placed in the Center, would view the Stars in the Heavens through those Holes respectively; each Star in the Heaven answering to its Representative on the Globe; and therefore the Longitude, Latitude, and other Affections of the Stars, may all be determined by means of the Apparatus to the artificial Globe, and made to correspond exactly with what we observed in Nature, or in the Heavens themselves.

Euphros. You take a good deal of Pains to inform my unexperienced Judgment in Things of so sublime a Nature:—But to come to the Point: Is there any Difficulty, arising from any different Methods in solving Problems, relating to the Rising, Setting, Southing, &c. of the

The Print of the Comet in the Magazine for the Month of May, 1758;—and the Print, which we gave to illustrate Mr. Brown's Letter in the last Magazine.

See also the large Print, intituled, The Wonders of the COMETARY WORLD displayed, &c.

Stars, more than what you have already shewn me, in regard to the Sun, Moon, and Planets?

Cleon. Very little, my *Euphrosyne*; for which Reason we shall soon dispatch that Affair. You have already been sufficiently taught the Doctrine of the Sphere, and the Use of the several Circles, particularly the *Circles of Latitude*, which belong to the Ecliptic; and therefore will here need no farther Description; and, I dare say, if I require you to assign me the Latitude and Longitude, the Declination, right Ascension, the Time of Rising, Southing, &c. of any particular Star, you will not need my Assistance for that Purpose. For example, you may try your Skill with the Star *Arcturus*; one of the most remarkable Stars of the first Magnitude, in the *Skirts of Boötes*.

Euphros. I am proud of the Task you have set me, and will give you a Proof of my Proficiency in the best Manner I can — The first Thing I have to do, I am assured, must be to rectify the Globe for this Place; and since a Star is the Subject, and can be seen only at Night, therefore some Hour of the Night must be supposed, which shall be Ten o'Clock this very Evening. — And now the Globe is rectified for that Time. And here, I see, *Boötes*, with his *Courfers*, and consequently, that bright Star *Arcturus*. — I remember you told me, if I brought the Pole of the Ecliptic to the Meridian, and fixed the Quadrant of Altitude over it; then, if I laid the Edge of the Quadrant upon the *Phænomenon*, (whether the Sun or Star) it would give me the Longitude, or Place thereof in, or reduced to the Ecliptic. — By doing this, I find the Longitude of *Arcturus* is about 20° of *Libra*; or 200° from the 1st Point of *Aries*; and that its Latitude from the Ecliptic is about 30° . — Again, if I bring the Star to the Meridian, I observe its Distance from the Equinoctial Line is about $20^{\circ} 28'$, which is its Declination Northward. — At the same Time, I observe the Meridian to cut the $211^{\circ} 9'$, which is therefore the right Ascension of *Arcturus*.

Cleon. Admirably well, my *Euphrosyne*. — Now for the Time of its Rising, Setting, and Southing, for the present Day, *August* the 9th.

Euphros. That I will proceed to: — But first, I must look

look for the Day of the Month on the Horizon, against which I see $16^{\circ} 30'$ of *Leo*, the Place of the Sun this Day at Noon, which Point of the Ecliptic I bring to the Meridian, and set the Hour Hand to XII.—Then I turn the Globe, till *Arcturus* appears in the eastern Horizon, and then the Index points out the Time of his Rising, viz. IX o'Clock this Morning.—I bring this Star to the Meridian, and the Index pointing to V in the Afternoon, shews that to be the Time of its Southing.—Lastly, I turn the Globe, till *Arcturus* is in the western Horizon, and the Index pointing to II, gives the Time of its Setting To-morrow Morning.—The Amplitude of its Rising is near 34° to the North; and so much is the Amplitude of his Setting of Course.

Cleon. You are so ready in the Praxis of the Stars, that I have little more to observe to you on that Head. It may not be amiss, however, to hint to you, that, when a Star is situate between the Ecliptic and the Equinoctial, its Latitude may be of one Denomination, and its Declination of another; thus, for Instance, *Aldebaran* in the *Bull's Eye*, has South Latitude and North Declination.—Another Thing I may observe to you, and that is; there is a Sort of *Poetical Astronomy* with regard to the Stars; or, there is what we call the poetical Rising and Setting of the Stars, which was much taken Notice of by the ancient Poets, Historians, and Husbandmen, (which you will readily observe in the Writings of *Hesiod, Homer, Ovid, &c.*) as it was the principal Method, by which People, in that Part of the World, and in those Days, distinguished the Changes and Diversity of the Seasons. Of these Risings and Settings, there were three Kinds, as follow. First, the *Cosmical* Rising of a Star, which is, when it rises with the Sun; but the *Cosmical* Setting is, when it sets at the Time the Sun rises. Secondly, the *Acronical* Rising of a Star is, when it rises at the Time the Sun sets; and the *Acronical* Setting is, when it sets with the Sun. Thirdly, the *Heliacal* Setting of a Star is, when it approaches so near the Sun, as to disappear in its Beams; and when it emerges from its Beams, or again becomes visible, then it is said to rise *Heliacally*.

But these Things we shall illustrate hereafter. To be farther insisted upon at present would be mispending of Time, and though you are well versed in those Poets, yet, till you have learned their astronomical Distinctions of the Seasons, by the Rising and Setting of the Stars, and by the Globe properly constructed to shew them, it will not avail you to have any Examples of this Sort to practise; but when you have that, it will open a fine Field for your *Physico-Poetical* Speculation, and View of distant Times.

Euphras. I will make it my Business to prosecute that particular Part of Study, as I apprehend there will be something very curious:—But what other Problem am I next to practise on the Globe?

Cleon. One other, the most considerable and entertaining of all, and that is,—to shew me the Face of the Heavens, or what Stars will be visible on the First Day of *October*, at IX at Night?

Euphras. Considering the Nature of this Problem, I find it is doing but little more than I have done before; but as it is of so general and curious a Nature, I will proceed to it Step by Step.——First, I rectify the Globe to the Latitude of *London*;——then the Sun's Place for that Day at Noon is $7^{\circ} 30'$ of *Libra*, which Point I bring to the Meridian, and set the Hour-Index to XII.—Then I turn the Globe about, till the Index points to X at Night,—and there letting it rest, I see, in one View, all the Stars which then appear above the Horizon; together with all the Constellations in which they are contained.—This is a noble Problem, *Cleonicus*, indeed! For, as by this, I shall be able, on the Evening of any Day, to represent the Stars visible for any Hour of the Night, I can very easily learn to distinguish the Constellations in the Heavens, by those on the Globe; at least, I shall be able to remember, to what particular *Asterism* any Cluster, or Assemblage of Stars belong, which I at any Time view in the Heavens. Also, by this Means, I shall imprint in my Memory the Idea of all the principal Stars; especially those of the first and second Magnitude, and shall soon be able to call them all by their Names.

Cleon

Cleon. This is the grand Design and Use of the celestial Globe, which is, as it were, the *Primer* of Astronomy, by which our Youth are instructed in the celestial Characters, and taught, as it were, to read in the starry Heavens—There are yet other nobler Uses to be made of the celestial Globe; one Instance I shall give you in Navigation, the most beneficial of all Sciences, which is, to find the Hour of the Night, by having the Latitude of the Place, and the observed Altitude of a Star given.

Euphros. As I am not so clear in this Problem, as in some others, I fancy, I had better see you perform the Thing, than attempt it myself, lest I should blunder about it.

Cleon. The Method is very easy. Thus:—Suppose in the Night, following the First of *October*, a Person was to take the Altitude of the Star *Bellatrix*, and find it just 30° in the Latitude of $51^{\circ} 30'$. Then to find the Hour, nothing more is requisite, than to rectify the Globe for that Day and Latitude.—Then, I bring the Quadrant of Altitude towards the Star *Bellatrix*, in the Left Shoulder of *Orion*, (which is in the Eastern Hemisphere) and then, moving the Globe and Quadrant so together, till the said Star comes exactly under the 30° of the Quadrant.—Here I let the Globe rest; and, if you look at the Index, you will find the Time is thereby shewn to be Half an Hour after I. in the Morning.

Euphros. By the Manner of your performing this Problem, I see it is very easy, and will shew the Hour of the Night by Land, as well as at Sea; to which Purpose, I shall now and then apply it by Way of Amusement.

Cleon. In all these Problems of rectifying the Globe for any particular Time, you observe, among other Things, the Course or Position of that remarkable *Phænomenon*, called the *Galaxy*, or *Milky Way*, among the Stars in the Heavens for that particular Time. Thus, for Instance, on the First of *October*, at X at Night, you will observe the *Galaxy* to pass exactly through your *Zenith*, or over your Head in the Heavens, and to cut the Horizon of Course at right Angles in the

the E. N. E. and W. S. W. Points of the Horizon; and it is very rare, that ever you see it in such a Position; as to divide the visible Hemisphere into two equal Parts; as there is but one other Time of the Year in which you can observe it.

Euphros. This is a curious Affair, and I shall diligently attend to such Appearances.———One Thing farther I have taken Notice of since I have been inured to the Use of this Globe; and that is, that several of the Stars never set in our Latitude, but are visible the whole Night; and, on the other Hand, that several Stars and Constellations never appear above our Horizon, or are seen by us at all.

Cleon. It is rightly observed, my *Euphrosyne*; and the Reason is evident from the very Position of the Globe itself; since all those Stars, which are at a less Distance from the North Pole than the Latitude of the Place, must necessarily circulate about the Pole above the Horizon, when on the North Part of the Meridian; and, on the other Hand, those Stars, whose Southern Declination exceeds the Complement of the Latitude, can never appear above the Horizon, which you well remember in the Case of the *Comet* at our last Interview.

DIALOGUE IX.

Of the PRECESSION of the EQUINOX, MUTATIONS of SEASONS, and the Celestial Phænomena, resulting from the retrograde MOTION of the EARTH'S AXIS about that of the ECLIP-TIC, illustrated by a NEW CONSTRUCTION and Apparatus of the CELESTIAL GLOBE.

Euphrosyne.

I Suppose in the preceding Dialogue you pretty well considered the principal Uses of the stellated Globe; not that I am weary of these celestial Studies; if any Thing

Thing farther remains, I shall be all Attention to understand it.

Cleon. There is only one Particular more of Consequence to be considered, which is a Point of a very curious and sublime Nature. I have formerly mentioned to you something of this Matter; when I told you, that the North Star, whose Motion is now altogether insensible, will, in other Ages of the World, have a Motion like the rest of the Stars, extremely obvious, round other Points in the Heavens — In short, the whole Affair is this; the Globe of our Earth has another Motion besides those already mentioned, when we discoursed of the *Orrery*, which is properly a *conical Motion* of its Axis about the Axis of the Ecliptic, by which Means, the Poles of the World have a Motion about those of the Ecliptic. This Motion is retrograde, or contrary to the Order of the Signs, and, in Consequence of this, not only the celestial Poles, but the Stars that are near them, and, indeed, all that we see in the Heavens, must necessarily appear, in Course of Time, to move forward. This Motion of the Earth's Axis backward is, indeed, very slow, being only at the Rate of about $50''$ in a Year, or 1° in 72 Years; therefore to move through 360° , or a whole Circle, will require no less than 25920 Years; and in that Space of Time, the Stars will all of them have an apparent Motion quite round the Heavens; from whence you will understand, that those, who live in the different Parts, or Ages of this great Period, will necessarily see the Stars in different Parts of the Heavens; for since the Place of each Star moves forward one whole Degree in 72 Years, the Change of their apparent Places will be very evident in the Space of one Century, and therefore, from one Age to another, the Longitude of the Stars will be continually increasing, till they have completed one entire Revolution through the Heavens.

Euphros. This to me is a new Doctrine, and as it conveys such wonderful Ideas, I shall think myself extremely happy, if I can understand it by any Means, or mechanical Contrivance, applied to the Globe; for I observe, you have made a Provision of that Kind, as I here see a Globe with such Appurtenances as are not usual

usual or common; by which, I presume, you are to explain this *Phænomenon* to me.

Cleon. That is the Design of this new Construction, my *Euphrosyne*.—There are several Ways, by which this Motion may be easily represented to you; one is, by this new Disposition of the celestial Globe; others you will see hereafter.—This Globe is so contrived, that the Poles of the Equinoctial are made to move at Pleasure round the Poles of the Ecliptic, and so to represent the Face of the Heavens for any Time of that long Period above mentioned, namely, *twenty-six Thousand Years*.—The late Mr. *Senex*, among many other Improvements of the Globe, contrived this principal one: By Means of these Pieces of Brass, which you see on either Side of the Globe; in one End of each is a Piece of Iron, fixed and applied to the Brass Meridian as usual, to give the Globe a Motion on the Axis, or Poles of the World.—The other End of each Brass Arm is applied to the Poles of the Ecliptic, in such a Manner as that it may be fixed, or moveable, at Pleasure. By this Means, the Poles of the World, or of the Equinoctial, may be placed in any Position about the Poles of the Ecliptic; and as they revolve, they will describe a Circle of 47° in Diameter, about the said Poles in the Ecliptic.—And to make the Idea still more easy and familiar to you, I have added to this Invention a *moveable equinoctial Circle* with its *Colures*, and also a *moveable Ecliptic*; whence, by a few Examples of the Use of the Globe, thus furnished and constructed, you cannot but understand—how all the Stars must have an apparent Motion forward in the Heavens;—how their Longitudes and Declinations must be constantly altering;—how various the Times of their Rising and Setting must be;—how those which are visible, in one Age, become invisible in another;—the Change of Seasons through all the Months of the Calendar;—and what is usually called the *Precession* of the *Equinoxes* by Astronomers; I say, how all these great *Phænomena* are produced by this one simple Motion, you will now see explained by Example.

Euphros. This will give me the greatest Pleasure. Pray, proceed.

Cleon. The first Thing I do is, to loosen the Brass Arms upon the Poles of the Ecliptic, by which Means, you see how easily I move the Poles of the World to any different Part, from where they now are.—I will move each Pole one fourth Part, or 90° from the Position they are now in, and there fixing the Brass Pieces, the Globe will revolve on the Poles of the World in the same Manner as before, and will exactly represent the Face and Appearance of the Heavens for that Time to come, or future Age, which is One-fourth Part of the forementioned long Period of Time: (*i. e.*) You now see the Globe, as it will be rectified by the People who live 6500 Years hence.—Here the following Particulars you will observe, (1) That the Elevation of the Pole is always the same, the Latitude of the Place not being at all affected by this Motion; therefore I still set $51^{\circ} 30'$ of the Brass Meridian to the Horizon. (2) You observe, that the equinoctial Points, by this retrograde Motion of the Pole, has receded from the first Point of *Aries* to that of *Capricorn*; for there the moveable Equinoctial intercepts the Ecliptic. (3) From thence you learn, that, at that Time of the World, the vernal Equinox will happen about the 22d of *December*, the Time which is now our Mid-winter. (4) That, as the Equinoctial Points have moved through three Signs backward; so the Stars must of Course appear to have moved as much forward; that is, their Longitude will be increased 90° . (5) As the moveable Equinoctial now contains an Angle of $34^{\circ} 30'$ nearly, with the fixed or present Equinoctial; so the Declination of Stars will be much altered thereby; (6) for those which had none before, may now have a Declination of any Quantity less than $34^{\circ} 30'$. (7) Those Stars, that had *South* Declination before, may now have their Declination *North*; and the North Declinations may be changed to *South*. Thus, at present, *Cor Leonis* has about 14° North Declination; in that Age its South Declination will be greater: the same you observe of many other Stars. (8) Those Stars and Constellations, which are now always visible, will then rise and set. Thus *Charles's Wain*, or *Great Bear*, at present, never goes below, or near the Horizon; but in the distant

Age,

Age, we are speaking of, it will be got almost wholly below the Horizon; as you see by revolving the Globe. (9) On the Contrary, those Stars, which now rise and set, as the Constellations, *Delphinus*, *Sagitta*, *Vulpecula*, *Andromeda*, &c. will then be constantly visible. (10) The present Pole-Star, which has now no sensible Motion, and is always nearly the same Height above the Horizon, will then appear to circulate round the then Pole of the World, and will have a Difference of Altitude upon the Meridian, of full $64^{\circ} 30'$. (11) A Star, or Point in the Heavens, now between the Head and Right-hand of *Cepheus*, will then be the North Pole of the World, and appear without Motion. (12) Stars, which are now altogether invisible to us in the Southern Hemisphere, will rise above the Horizon to the View of that Age. Thus *Corona Australis*, *Indus*, *Grus*, *Phœnix*, *Toucan*, *Pavo*, *Ara*, and *Lupus*, will then be among the Number of visible Constellations, which are all of them at present invisible to us. On the other Hand, *Canis Major*, great Part of the *Hydra*, *Crater*, &c. will then be invisible to that Age, which are now so conspicuous above our Horizon. (13) In that Age, when the Sun possesses the same Part of the Ecliptic, the same Stars will rise at a very different Time from what they now do. Thus, when the Sun is in the first Degree of *Cancer*, on the present *Midsummer-day*, *Cor Leonis* rises at about Half an Hour after Eight in the Morning; but in that Age, it will rise at near Eleven, which will then be the Day of the autumnal Equinox. (14) The Amplitudes and Azimuths likewise will then be very different from what they are now. Thus, at present, on *Midsummer-day*, *Cor Leonis* rises on the E. N. E. Point of the Compass; but, in that Age, its Amplitude will be South, near two Points and a Half. (15) You will easily observe, from all that has been said, that the Seasons of the Year will have changed their Places in the Calendar; for the vernal Equinox will be on the 22d of *December*, *Midsummer-day* on the 21st of *March*, the autumnal Equinox the 22d of *June*, and the Middle of Winter about the 23d of *September*. These, and many other Particulars, naturally and necessarily follow from altering the Position of the Poles of the World.

Euphros. It is really very wonderful, to consider how many surprising and important Changes happen from so small a Cause, as one would think that to be: I cannot but say, those Things are very evident, by Means of this Apparatus; but I believe, without it, I could never have attained to any distinct or clear Ideas of such a new and complicated System of mundane Changes; and from this first Example, I can plainly foresee, that, if you remove the Poles of the World backward, through another Quarter of a Circle about the Poles of the Ecliptic, those Alterations and Changes will still appear much greater than before, with respect to the Time, Seasons, Motions, and various Phenomena of the heavenly Bodies.

Glean. Indeed they will; and you shall see by my removing the Poles to the Places you mentioned, what an Aspect the Heavens will have in so distant a Period as 13000 Years hence.——The Poles are now fixed diametrically opposite (on the other Side of the Poles of the Ecliptic) to the Place they at present possess;—and now, as the Globe revolves, you see what wonderful Mutations ensue; for now that very Star, which is our North Pole, and appears fixed, will, in that Age of the World, appear to describe a Circle round the then North Pole of 94° Diameter;——that it will transite the Meridian at $8^{\circ} 30'$ to the South of our Zenith, on one Part, and descend so low as to be within $5^{\circ} 30'$ of the Horizon on the other.——The Seasons of the Year are then diametrically opposite to what they now are in the Calendar; our *Midsummer-day* will then be when the Sun enters the first Sign of *Capricorn*, and the first Degree of *Cancer* will be farther distant from the North Pole at that Time, and will then be the Winter Solstice: Also, the Vernal and Autumnal Equinoxes will then have interchanged their Days.——The Constellations within $23^{\circ} 30'$ of the Southern Pole of the Ecliptic on one Part, will then be visible above our Horizon; as *Musca*, *Crociens*, *Apus*, *Triangulum Australe*, &c. and, on the other Hand, many Stars of the first Magnitude will then entirely disappear from our View, as *Sirius*, the *Dog Star*, *Regel*, those in *Orion's Belt*, will be Stars unknown, at least unseen,
by

by the People of that Age, though, at present, they shine with the greatest Lustre in our bespangled Canopy. — There will, likewise, be then the greatest Difference in the Declination of Stars; as those which have now $23^{\circ} 30'$ of North Declination may then have just as much South; all which you readily perceive without enlarging farther on Particulars.

Euphras. This is, indeed, a most noble Invention, and must certainly be reckoned amongst the most curious Improvements of the Globe. I see, by this Means, it is easy to represent every past and future Age to our View, with regard to the celestial Phenomena. I make no Doubt, but the Learned can convert such a Doctrine as this to some very useful Purposes. If there be any such, that I could be informed of without too much Trouble, I should be very glad.

Cleon. The Uses that are made of this Motion of the Earth are some of them very considerable; for hence you learn at once, that, since the equinoctial Points move backward, it will easily account for the Motion of the Stars and Constellations forward. Thus, for Instance, you see, upon all the celestial Globes, the Constellations *Aries*, *Taurus*, *Gemini*, &c. are now removed to the Distance of one whole Sign, from the Signs that bear the Names of those Animals. Thus, the Constellation *Aries* is moved forward into the Sign of *Taurus*, *Taurus* into *Gemini*, and so on.

Euphras. By this, I suppose, you would have me understand, that, in some Ages past, the Vernal Equinox was in that Part of the Ecliptic where now the Constellation of *Aries* is, and that then, the Constellation and its Sign were both of one Name. Pray, how long since may that be, do you suppose?

Cleon. It was upwards of 2000 Years ago, at which Time some great Men, who first observed the heavenly Bodies, lived; particularly *Hipparchus*, from whom we learn the Equinoctial Colure passed not far from the bright Star in the Head of *Aries*. — And to gratify your Curiosity, as well as to inform your Understanding, I have here the Copy of a very antique Globe, found in the Ruins of ancient Rome, and is now in the Museum of the *Farnesian* Palace, as the most curious Monument of Antiquity.

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Plate XXXVI



Fig. I.



Fig. II.

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Upon this Globe, you see the various Asterisms as they were depicted by the Antients, and amongst them the 12 Constellations of the Zodiac; all of them placed in their proper Signs, and near to the Beginning of them. Thus, you see, the equinoctial Colure passing through the right Horn and Foot of *Aries*, not far from the equinoctial Point; the solstitial Colures likewise pass through *Cancer* and *Capricorn*, and not through *Gemini* and *Sagittarius*, as they now do; and the same you observe of all the rest*.

Euphros. I think, I may truly say, this is one of the most curious Things I ever saw.—One may learn from hence almost the Age of the Globe.—But I observe the equinoctial Point is removed backward from the Colure which passes through the Foot of the *Ram*, whence it should seem, that this Globe was made some Time after the equinoctial Point was in that Colure. Pray, how do you conjecture concerning the Age of this Globe?

Cleon. Probably we may reason thus. The equinoctial Colure (passing through the bright Star in the Head of *Aries*, and its Foot) appears about 5° from the equinoctial Point on the Globe, which, at the Rate of $50''$ per Annum, will give about 360 Years from the Time it had that Situation, to the Time the Globe was made.

* As very few of our Readers can have the Sight of this antique Globe and its Constellations, and thereby an Opportunity of observing the Difference between that and the present celestial Globe, we have thought it proper (to assist the Imagination as much as possible) to add a Copper-plate Print, representing the Constellation of *Aries* on both Globes: Especially, as it will represent to the View the different Positions of the equinoctial Points, with regard to that Constellation; for in Fig. I. of this Plate, the Position of *Aries* is represented, as it appears on the antique Globe, in its proper Sign, near the Equinox; but in Fig. II. the said Constellation is represented, as it appears on the modern Globe, removed from its own Sign into that of *Taurus* more than 30° from the equinoctial Point, by which a clear Idea of the Recession of the Equinox is plainly exhibited to the View; and this we thought necessary should be done, as it is a Subject of the greatest Importance and Consequence in the Sciences. (See Plate XXXVI.)

The bright Star of *Aries* is now not quite 30° from the present equinoctial Point; this Point has therefore probably receded through 25° , since the Time this Globe was made; but 25° reduced to Time will give 1800 Years for the Age of the Globe; so that it seems probable, this Globe was made about 40 Years before *Christ*: to which if we add the 360 before mentioned, it will give 400 Years before *Christ*, for the Time in which the said Colure passed through the bright Star of *Aries*; but in such Computations we must not stand for a few Years.

Euphros. You not only shew me these wonderful Things in Theory, but confirm them by real Facts. This antique Globe is itself a real Demonstration of all your astronomical Theory of the retrograde Motions of the equinoctial Points, and the mutable Phænomena of the Heavens depending thereon. Are there any other Uses to which this Affair may be applied?

Cleon. Yes; very great Uses in Chronology; when you are dextrous in the Use of this new constructed Globe, you will be able, pretty nearly, to give a Guess at the Distance of Time in which any Poet or Historian lived, whom you find mentioning the Rising and Setting of the Stars, the Places of the Equinoxes, Solstices, &c. because you have nothing to do but to alter the Position of the Poles of the World, till the Globe, by its Revolution, shall give the same Time of the Rising and Setting of those Luminaries, and then the Distance between the present equinoctial Point and that on your Globe, so rectified, will, when turned into Time, give the Age in which they lived.

Euphros. This being a Thing of so curious a Nature, and what, I apprehend, I can perform myself on the Globe, when I have seen the Process by you, I don't know any Thing would be more highly grateful than your illustrating this Matter by an Example.

Cleon. It must certainly afford you a pleasing Satisfaction, to know, from your Globe, the Age, or Time, in which any of our celebrated Heroes of Antiquity lived, and how the Face of the Heavens appeared to them; and that you may thoroughly comprehend the Thing, I shall give you for a Problem, to determine the Age and Time of

of *Hesiod*, from a Passage in his Poem, wherein he described the *acronical* Rising of the Star *Arcturus*, in the following Lines :

*When the glad Sun, approaching with his Rays,
Has from the Tropic run out sixty Days;
Arcturus, rising from his sacred Bed,
Is first discover'd in his Ev'ning's Shade.*

From these Lines it is evident, that in *Hesiod's* Time, when the Sun had passed the Winter Tropic, by the Space of 60 Days, and was then of Course in the Beginning of the Sign *Pisces*, the Star *Arcturus* was rising in the East at Sun-set. — But in the present Age, if you take the common Globe, and rectify it for the Latitude of *Africa*, the Birth Place of *Hesiod*, in Greece, whose Latitude is about 38° , you will find, when the Sun has just entered *Pisces*, and is setting in the western Horizon, that there is no Appearance or Rising of *Arcturus* in the East; — but that Star will appear then at a great Distance below the Horizon, and rises not to the Inhabitants of Greece till near three Hours after Sun-set, on the 20th of February in the present Age*.

* As there has never yet been any Print of this new Apparatus of the celestial Globe, I thought it would be very acceptable to the ingenious Reader, to have a View of the celestial Globe, as constructed with the said Apparatus of moveable Poles, Ecliptic, Equinoctial, and Colures, rectified for the Age and Birth-place of *Hesiod*, agreeable to the above mentioned Example. In the 1st Fig. of this Plate, is represented a View of the eastern Hemisphere of the Globe, shewing *Arcturus* rising in the North-east Part of the Horizon, and in the 2d Fig. is a Representation of the western Hemisphere, shewing the Setting of the Sun at the same Time that *Arcturus* rises; both these together exhibit a View of the Constellations, such as they appear on the Surface of a Globe, 3 Inches in Diameter; and the Reader will farther observe, that the Circles represented by two black parallel Lines are the Colures, Ecliptic, and Equinoctial, as they were posited on the Globe in *Hesiod's* Time; but the double dotted Line shews the Equinoctial, as it is now placed on the present Globes, and the single dotted Lines shew our present Tropics. By this Means, the Reader will easily perceive the Difference between the Positions of the great Circles of the Globe at those two distant Periods of Time, and consequently, will thereby become more easily instructed in the *Rationale* of the above *Praxis*, or Use of this new constructed Globe.

Euphros. All this I plainly understand from the Use of the common Globe.—I must readily infer from thence, that some Alteration must be made in the Disposition of the Globe, that shall shew that Star rising in the Latitude of *Greece*, when the Sun is setting in the Beginning of *Pisces*.—Let me have the Pleasure of seeing how that is performed.

Cleon. As many Ages have passed since *Hesiod's* Time; and, since, I have before shewn, that, in every 72 Years, the equinoctial Points go backward *one Degree*, you will find no Difficulty of understanding that, in order to represent the Face of the Heavens for any Time past, the said equinoctial Points must be moved forward, at the Rate of *one Degree* for every 72 Years, till you arrive at the Time proposed; and by this Means, the Phænomena of any Age described may be soon represented; since, by moving the equinoctial Points, and thereby giving a new Position to the Equator, and Signs of the Ecliptic, you will at length find them such as will exactly answer to, and solve the Appearances mentioned.—Thus, you see, I loosen the Brass Arms upon the Poles of the Ecliptic, and gently revolve the Globe about them, till such Time I have made the Equinoxes advance forward in the Ecliptic to about 6° of *Taurus*,—and there screwing the Poles fast, and rectifying the Globe for the Latitude of *Asra*, 38° , and bringing the Sun's Place in the Beginning of *Pisces* to the western Horizon, if you cast your Eye on the Eastern Side, you will see *Arcturus* rising; and as this is the very Thing which *Hesiod* affirms he saw, it is evident that this was the proper Disposition of the Globe; or, that the Poles of the World, the Equator, the Equinoctial, and the Ecliptic, had the same Position then, with regard to the Stars in the Heavens, as you now see they have to those on the Surface of the present Globe.

Euphros. I observe all that you mention with the highest Satisfaction, and am readily convinced, that the Face of the Heavens, now represented, is the same that was in *Hesiod's* Time.—But how do you infer from thence, the Number of Years that has since elapsed?

Cleon. Very easily; because you will observe, the equinoctial Point has been moved forward from the Place

Place where it now is, in the Beginning of *Aries*, through 36° and $15'$ into *Taurus*, and for every Degree we must allow 72 Years; therefore $36\frac{1}{4}$ Degrees will give 2600 Years, which is the Distance of Time from hence, that *Hesiod* lived, which was therefore 840 Years before the Christian *Æra*; which makes him contemporary with *Jehu*, King of *Israel*, and *Jonah* the Prophet, according to our best Chronologers.

Euphros. Well! this is a most delightful Solution and Discovery to me. I little thought any such Use could have been made of the Globe. I can scarce help fancying myself living at that Time, as every Thing appears to me in this artificial View, as it did to them in Reality.

Cleon. By another Passage from *Hesiod*, you will find this Disposition of the Globe farther confirmed, to answer the Appearances of his Time. He says, or rather sings,

*But when Orion and the Dog-star come
To the Mid-region of the heav'nly Dome,
The Morn, that blushing draws away the Night,
Beholds Arcturus in the dawning Light.*

From whence it is plain, that in *Hesiod's* Days, when the three bright Stars in *Orion's* Belt were upon the Meridian, *Arcturus* then appeared in the eastern Horizon;—and just the same Thing you see upon the Globe.—The Constellation of *Orion* is on the Meridian, the *Dog-star* near it, and *Arcturus* upon the North-east Point of the Horizon, all exactly answer to *Hesiod's* poetical Delineation.—I might farther insist on those useful Problems, by pointing out the particular Seasons of the Years, with regard to the Stars, as described by *Hesiod* and other Poets. Thus in another Part of *Hesiod's* Poem, we find the following Lines;

*Begin the Harvest as the Pleiads rise;
And take the Plough, when they withdraw the Skies;
For forty Days and Nights their glimm'ring Light,
Obscur'd to us, no longer cheers the Sight.*

Here we have a beautiful Description of the *Heliacal* Rising and Setting of these Stars, and shews how different their *Plowing and Harvest Seasons* were from our's. In like Manner, many other Illustrations of poetical

Passages and Descriptions, from such an Apparatus of the celestial Globe, may be derived.—Thus, for Instance, when *Virgil* tells us in his *Georgics*,

*Around our Pole the spiry Dragon glides,
And like a winding Stream the Bears divides ;
The Less and Greater, who, by Fate's Decree,
Abhor to dive beneath the Northern Sea.*

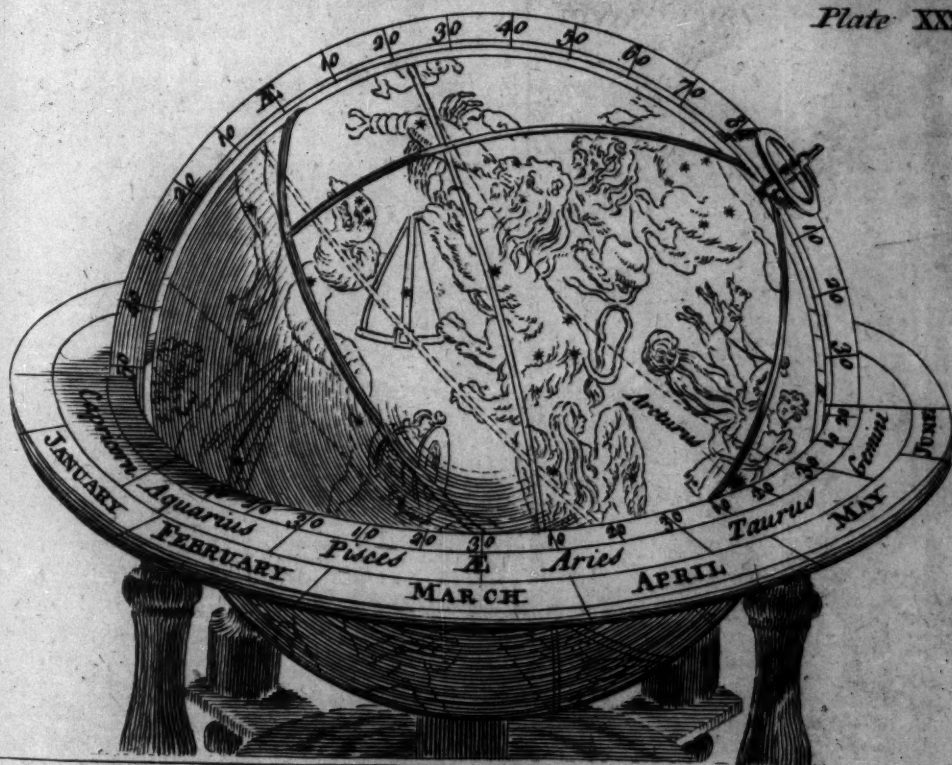
Now these Lines are much more properly applied to the *Dragon* and *Pole-star* in *Virgil's* Time than in our own; because the *Dragon* did then, in some Measure, encompass the Pole, and divide the Pole from the *Greater Bear*, as you easily see, by rectifying the Globe for the Time of *Virgil*, which was about 1780 Years ago; at which Time, the Equinoxes were in 23° of *Aries*, and gave the North star that Position, with regard to the *Bear* and the *Dragon*, which he mentions; but in our Age, the North Pole is situated entirely without the Folds or Windings of the *Dragon's Tail*; nor is it now between the *Lesser* and the *Greater Bear*, as it was very exactly in his Days.—I must leave you to improve in this so sublime a Praxis on the Globe at your Leisure, having said enough, I am well assured, to give you the general *Rationale* of Procedure in all such Cases; and shall conclude with the Words of an eminent Author, which are as follow: “But the Inspection of the Globe, “when it is fixed in a proper Position, will convey the “best Idea of all these Appearances; for we derive this “Advantage from the new Construction of it, that it “will enable us to place the several Phænomena before “every Eye; by which Means, those who have the “least Acquaintance with these Studies, must be greatly “surprised, and pleased, to observe the antient Accounts “minutely verified; it is a Sort of living over again “the former Ages, allowing $1^{\circ} 23', 30''$ for every 100 “Years, according to *Flamsteed*.”—I shall not now suggest some other Purposes that might be served by this Method. It is sufficient, to recommend the Invention, that it throws so much Light on the common Classics, and answers such very great Purposes in Astronomy, History, and Chronology.

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The CELESTIAL GLOBE *rectified*
for the AGE & BIRTH-PLACE *of* HESIOD

Plate XXXVII.



DIALOGUE X.

Of the DESCRIPTION and USE of the
TERRESTRIAL GLOBE.*Euphrosyne.*

AS the manifold Uses of the *Celestial Globe*, which in our former Conversations you have been so good as to make me acquainted with, have so much enlarged the Ideas of my Mind, and given me a rational Delight and Improvement, so much beyond my Expectation, I gladly embrace the present Opportunity of continuing such useful Speculations, though on a different Subject from the former.—We now descend from the spangled Heavens to contemplate the variegated Figure of the Earth, and to observe the Analogy between the real Globe on which we live, and that artificial one, in Miniature, which I see here on the Table.

Cleon. The present Minutes will, I hope, afford you a pleasant Survey, as well as compendious View of the several Parts of our Earth, exhibited on the Surface of this terrestrial Globe; and the first Thing that I think proper to observe to you here, is, the Form of it.

Euphros. The Form, I presume, will not require much to be said of it, as it is evidently of a round, or spherical Figure.

Cleon. It is so, indeed, with respect to the *artificial Globe*, you here see, which is as perfectly spherical as Art can make it.—But you are not to suppose, that the Figure of our Earth is, therefore, so too; for this is found, by Experience, to differ considerably from the Figure of a Globe; in other Words, the Diameter of the Earth, at the Equator, exceeds that considerably which passeth through the Poles, as I shall farther observe to you by and by; so that the true Figure of the Earth is, what the Mathematicians call a *Spheroid*, and not a *Sphere*.

Euphros. How then can this artificial Globe be an adequate Representation of the natural One, *Cleonicus*? Or, why do you represent a *Spheroid* by a *Sphere*?

Cleon You will easily see the Reason of that, when you consider, that the Difference of 70 or 80 Miles is considerable between the Diameters of the Earth, whose Dimensions are nearly 8000 Miles ; but altogether inconsiderable and imperceptible in the small Dimensions of a Globe, whose Diameters exceed not 20 or 30 Inches.—'Tis true, if Gentlemen, who are possessed of large Fortunes, were disposed to expend those Sums of Money this Way, which are oftentimes, with great Profusion, lavished away on many useless Subjects, we might then expect to have Globes of such a Size, as might sensibly represent the Difference in Diameter, or the true *spheroidical* Figure of the Earth. For this Purpose, a Globe, ten Feet in Diameter, would suffice:—On such a Globe, you would observe the Island of *Great Britain* have a different Position, with regard to its Distance from the Equator, than what it would have if the Globe was truly *spherical*:—But these large Globes we can better sustain the Want of, as their Use is, in a great Measure, supplied by Maps, or Projections of some particular Parts of the Surface, as we shall hereafter see; and, at the same Time, shew, that though the Neglect of the true Figure of the Earth be excusable in Globes, it is, nevertheless, unpardonable in Maps, where it may be so easily provided for, and where the Position, Distance, and Dimensions of Places so evidently require it.

Euphros. I must stay till then for farther Instructions in that Point—As to the Dimensions of the Globe, I think, you observe, it is near 8000 Miles in Diameter; but, pray, how do you find that by Experiment?

Cleon. In this Manner, my *Euphrosyne*.—If the Earth were a perfect *Plane*, you might go ever so far North or South, without observing any Alteration in the Height of the Polar Star above the Horizon;—but if the Surface of the Earth be of a *spherical* Form, you move in the Arch of a Circle, and, as you move, your Horizon will move through an equal Arch in the Heavens.—If you move northward, your Horizon will descend below the North-star, and therefore that Star will appear to rise above your Horizon;—but, if you go directly South, your Horizon will descend in the southern Part, and rise in the northern Part; so that the Distance between the North-

star

star and the Horizon will be thereby lessened, and this will be the Case every where.—Lastly, it is found, by Experience, that, if you go $69\frac{1}{2}$ of our *English* Statute Miles directly towards the North or South, you will elevate or depress the Polar-star just one Degree; and since there are 360° in the whole Circumference, it will produce 25020 Miles, for the Dimensions of a great Circle on the Surface of the Earth, from whence its other Dimensions may be easily deduced.

Euphros. What you have said, in regard to the Dimensions of the Earth, I can understand, without trying such a tedious and fatiguing Experiment. And I can, at the same Time, perceive the Reason why the Globe is thus moveable in the Horizon; because the Pole-star is, by this Means, elevated or depressed, according to the different Part of the Globe, in which we are supposed to be.—And from thence too, I infer, that the Distance which I am from the Equator must necessarily be equal to the Height of the Pole-star above the Horizon, measured in Degrees; for, if I suppose myself at the Equator, then, of Course, my Horizon will pass through both the North and South Poles; and, if I am supposed to be placed just under the Pole-star, then my Horizon coincides with the Equator; and consequently, wherever I am posited upon the Surface of the Earth, the Arch of a Circle, which measures my Distance from the Equator, must be equal to that which measures the Height of the Pole-star above the Horizon.

Cleon. Your Ideas are all very right, in regard to that Affair.—The Latitude of the Place is your Distance from the Equator, which, being always equal to the Elevation of the Pole, is the Reason why, when you rectify either Globe, you place the same Degree on the North Part of the Meridian to the Horizon, as expresses your Latitude from the Equator on the South Part;—and as you are already acquainted with the Nature and Uses of the various Circles, I need only just observe to you here, that, with regard to the Horizon, there are but three different Positions of the Sphere, viz. The First is, a *Right Position*. viz. when the Poles are in the Horizon, and the Equator and Parallels are perpendicular thereto, or intersected at *right Angles*.
Such

Such a Position of the Sphere have all those who live under the Equator.—Secondly, a *Parallel Position* of the Sphere is, when the Equator coincides with the Horizon, and the Parallels of Latitude are, of Course, *parallel* thereto: Such a Position of the Sphere you would have, if you were (as you just now supposed yourself to be) placed under the Pole.—Thirdly, the *Oblique Position* of the Sphere is that alone which is worth considering, as being general to all the Inhabitants of the Globe, except those before mentioned; and is so called, because of the *oblique* Positions of the Equator, and its Parallels to the Horizon. But on these Things there will be no Occasion to enlarge to you.

Euphros. You make me a Compliment, *Cleonicus*;—but though it be true, these Things are not difficult to be understood, and are almost obvious by Inspection; yet a few of your geographical Definitions respecting the Inhabitants of the Earth, and the Division of the Globe into Land and Water, will not be amiss, as I am now to form a regular Idea of this Science.—I shall leave you, therefore, to proceed in that Method which you judge best for my Information.

Cleon. You may always depend on my doing that; and, in the first Place, it will be necessary to observe, that the Surface of the Globe is divided into five Parts, or *Zones*, viz. the *Torrid Zone*, the two *Temperate Zones*, and the two *Frigid* or *Frozen Zones*.

1. The *Torrid Zone* is so called, from the Inhabitants being, as it were, torrified, or scorched with the Sun's Heat; for this part of the Earth is all that, which lies between the two *Tropics* of *Cancer* and *Capricorn*; and over which, the *Ecliptic Line* is obliquely posited; from whence you will easily observe, that the Inhabitants of this *Zone* will have the Sun perpendicularly over their Heads two Days in the Year, in passing from *Tropic* to *Tropic*, in each Half of the *Ecliptic*.

Euphros. I readily understand you, and I farther observe, that such People as inhabit *this Zone*, may, in some Sense, be said to have two Summers; for since the Sun, twice in the Year, passeth over them, those two Days, in which the Sun is in the *Zenith*, will be their *Mid-summer Days*, and the two *Tropical Days*, are those,

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those, in which the Sun will recede to the greatest Distance from them, and therefore may be called their *Mid-winter Days*.

Cleon. At the same Time too, you will understand, that, when the Sun is vertical to them, they can, at Noon-day, have no Shadow; in which Case, they were anciently called by the *Greeks*, *Ascii*, which imports the same Thing. But, at other Times of the Year, they have their Shadows falling North or South of them, according to the Place of the Sun in the *Ecliptic*; and they are then called the *Amphiscii*.—Also it may be observed, that only those People, who live just under each *Tropic*, have only one *Mid-summer*, in which the Sun is vertical, or over their Heads; they have also one Winter only, *viz.* when the Sun is in the opposite *Tropic*.

Euphros. I find, from what you say, that the Seasons of the Year very much depend on the Situation of the Inhabitants, in regard to those *Zones*; please, therefore, next to shew me how they are circumstanced, who live in the *Temperate Zones*.

Cleon. The *Temperate Zones*, are all those Parts of the terraqueous Globe, which lie between the *Tropics* and *Polar Circles*, and consequently, there is one of these in the *northern* and another in the *southern Hemisphere*, as you see, they are easily distinguished on the Surface of the Globe.—As we ourselves are Inhabitants of the *North Temperate Zone*, we find the Seasons of the Year in a temperate Degree; our Summer Suns are at a Distance from our *Zenith*, and we do not therefore experience the greatest Force of his Beams.—Again, we are never without his enlivening Influence the Space of one natural Day; so that, upon the Whole, we must reckon our Situation the best that the Surface of the Earth can afford; especially, the *Paradisical* Situation of *England*, which is in the most temperate Part of the *Temperate Zone*.

Euphros. I have always thought, that *England* was, on many Accounts, a favourite Country of Providence. Our Sex have particular Reason to think so. The ardent Beams of the Sun, on the one Hand, in regard to our Complexion, would be very unfriendly; and the Cold
of

of remoter Climes would by no Means suit the Tenderness and Delicacy of our Nature; most blisful, therefore, is our Department on the *British Isles*.

Cleon. It was an ancient Observation, that we should think ourselves almost too happy, if we were thoroughly sensible of all the comparative Benefits we enjoy above other Inhabitants of the Earth.—Since the Noon-tide Shadows of the Inhabitants of either *Temperate Zone* fall always one Way, they have been usually called by Geographers *Heteroscii*.—By revolving the Globe upon its Axis, you will see, that by far the greatest Part of the habitable Earth is situate in these two *Zones*.

Euphros. The very Name of the *Frigid Zone* is enough to make one shudder.—Their Situation, distant from the Sun, must prove them a hardy Race of Mortals; and yet, I have heard, there are such to be found within a few Degrees of the *Pole*.

Cleon. You mean the *North Pole*, my *Euphrosyne*; for about the *South Pole*, no Land has been yet discovered within the *Polar Circle*, as you will see, by casting your Eye upon that Part, and turning the Globe about at the same Time.—As these Circles circumscribe each *Pole*, at the Distance of $23^{\circ} 30'$, (the same Distance as the *Tropics* lie from the *Equator*) it will follow, that, when the Sun is in the *southern Tropic*, it will be 90° distant from the *North Polar Circle*, and consequently, all that Space, contained within it (improperly called the *Zone*) will be entirely bereft of the Sun-beams for one Day, or involved in Darkness.—Also, as the Sun advances from *Capricorn* to *Aries*, the Parts within the *Polar Circle* will be more and more enlightened, and of Course, the intense Cold, occasioned by the great Distance of the Sun, while in the southern Parts of the *Ecliptic*, will abate by Degrees, or become less severe.—As the Sun advances from *Aries* to *Cancer*, it will appear to the Inhabitants of the *Polar Regions* to be wholly above the Horizon, as you gradually pass from the *Polar Circle* to the *Pole*.—And, when the Sun is in the *Tropic of Cancer*, the constant Heat, upon all those Parts about the *Poles*, will be excessive great; and those Parts of the Earth that are coldest, at one Time of the Year, will alternately be hottest at another.—But, upon the Whole, the Effects of Cold are more durable

durable and prevalent than those of Heat; and therefore, these Parts of the Earth still deserve the Epithet, or Title, which they bear.—The Inhabitants, who live in these *Circles*, have their Shadows fall all around them, when the Sun ceases to set in their Latitude, and therefore were anciently called the *Periscii*.

Euphros. What other Geographical Distinctions have you with regard to the Inhabitants?

Cleon. Those which follow: (1.) Such as live diametrically opposite to each other are called *ANTIPODES*, as they are 180° distant from each other. The Times and Seasons will be contrary to each, *i. e.* when it is Noon to one, it will be Midnight to the other; and when it is Winter to one, it will be the Summer-Season to the other. They have the same Latitude; but one is North, and the other South: All which is evident, by viewing any two such Places on the Surface of the Globe. (2.) Those, who live in two opposite Points of the same Parallel of Latitude are called *PERIÆCI*. They have the same Length of Day and Night, the same Seasons of the Year, and, when it is Noon to one, it is Midnight to the other. This likewise is evident on the Globe. (3.) They who live under the same diurnal Meridian, but in two different Parallels, equally distant from the *Equator* on either Side, are called *ANTÆCI*. They have the same Noon-tides, but differ in all Things else: The Nights of one are equal to the Days of the other; and, when it is Summer with one, it is Winter with the other: All which Particulars are too easily observed on the Globe to need any farther Account.

Euphros. These Things I shall make myself very well acquainted with by a little Practice. Is there any Thing farther for me to know by Way of Definition.

Cleon. It may be proper just to mention, that there is a Distinction of the several Parts of the Earth, under the Title of *CLIMATES*. The Geographers call that Part of the Earth, contained between two Parallels of Latitude, a *Climate*, in which the Length of the Days differs by *Half an Hour*, of which there are of Course 24, on each Side of the *Equator*, all of a different Breadth from each other; for, according to the different Obliquities of the Sphere, the Differences of Latitude will be unequal among them—

themselves, that shall produce equal Differences in the Length of Days. This is a Point, in which you will be easily satisfied, by a little Practice on the Globe; and particularly, you will observe the Extent of each to be, as specified in the following *Table*, in the lower Part of which, you will find the *Climates* are differenced by the Space of a Month in the *Polar Circles*, of which there are six from the *Circle* to the *Pole*.

CLIMATES between the EQUATOR and the
POLAR CIRCLES.

Climates.	Hours.	Latitude.		Breadth		Climates.	Hours.	Latitude.		Breadth.	
		D.	M.	D.	M.			D.	M.	D.	M.
1	12 $\frac{1}{2}$	8	25	8	25	13	18 $\frac{1}{2}$	59	58	1	29
2	13	16	25	8	00	14	19	61	18	1	20
3	13 $\frac{1}{2}$	23	50	7	25	15	19 $\frac{1}{2}$	62	25	1	07
4	14	30	25	6	30	16	20	63	22	0	57
5	14 $\frac{1}{2}$	36	28	6	08	17	20 $\frac{1}{2}$	64	06	0	44
6	15	41	22	4	54	18	21	64	49	0	43
7	15 $\frac{1}{2}$	45	29	4	07	19	21 $\frac{1}{2}$	65	21	0	32
8	16	49	01	3	32	20	22	65	47	0	26
9	16 $\frac{1}{2}$	52	00	2	57	21	22 $\frac{1}{2}$	66	06	0	19
10	17	54	27	2	29	22	23	66	20	0	14
11	17 $\frac{1}{2}$	56	37	2	10	23	23 $\frac{1}{2}$	66	28	0	08
12	18	58	29	1	52	24	24	66	31	0	03

CLIMATES between the POLAR CIRCLES
and the POLES

Length of Days.		Latitude.		Length of Days.		Latitude.	
Months.		D. M.		Months.		D. M.	
1		67 21		4		78 30	
2		69 48		5		84 05	
3		73 37		6		90 00	

Euphros. If I understand this Matter right, I find, by the *Table*, that the first *Climate* ends at $8^{\circ} 25'$, and, of Course, is $8^{\circ} 25'$ broad; also, that the 10th *Climate* ends at the Latitude of $54^{\circ} 27'$, and its Breadth is $2^{\circ} 29'$; and because 10 Half Hours make 5 Hours, these added to 12, make 17 Hours, for the Length of the Day, where that *Climate* ends, as shewn in the 2d Column.

Cleon. You have a very clear Conception of this Affair, which, in itself, is of no great Consequence; but, as we usually speak of the *Climes*, or *Climates*, of different Countries, it is proper, that every one should have some geographical Idea or Notion of the Thing.

Euphros. You just now mentioned the geographical Descriptions of Land and Water. These, I suppose, come next in Order; and, in the first Place, please to let me know the Division, or Distinction of those Parts you call Land.

Cleon. It is customary with Geographers to make a Distribution of the Land into the following Classes.

(1.) Of CONTINENTS, which are the large Tracts of Land, including many Kingdoms and Countries, not any where separated by the Sea, of which we may reckon five; namely, *Europe*, *Asia*, *Africa*, *North America*, and *South America*.

(2.) Of ISLANDS: These are Tracts of Land every where environed with Water; such as you see here on the Globe, viz. the Island of *Great Britain*, *Madagascar*, *Sicily*, *Borneo*, *Nova Zembla*, &c.

(3.) Of PENINSULAS: These are Tracts of Land surrounded by Water on every Side, but one small Part, which joins it to the Continent. Thus, you see, on the Globe, the Country called *Morea*, joined to *Greece*. Thus you see also, *Africa* is a Sort of Peninsula, joined to *Asia*, by a narrow Tract of Land, between *Egypt* and the *Red Sea*.

(4.) Of ISTHMUSES: These are the narrow Necks of Land, by which the *Peninsulas* are connected with the Continent: As the *Isthmus* of *Corinth*, which joins the *Morea* to *Greece*, as you see on the Globe.

(5.) Of PROMONTORIES: These are large Heads or Capes of Land, which stand out into the Sea; such as the *Cape of Good Hope*, in *Africa*; *Cape Horn*, in *America*;

rica; *Cape Finisterre*, in *Spain*, &c. which readily shew themselves on the *Globe*: And these are all the great *Forms of Land*, the *Surfaces of which* are diversified with high and low *Parts*, commonly called *Hills*, *Mountains*, *Vales*, &c. of which there need no *Description*, as you have so lately read an *Account of the Alps*, of *Mount Vesuvius*, and of the *Pike of Teneriff*, which are the most remarkable in the *World*.

Euphros. These *Subjects* afford me the highest *Pleasure*, even while I am a *Novice in Geography*. But, when I become better acquainted with the *Science*, the *Delight in Reading* will increase in *Proportion*: Therefore, next, pray tell me what are the *Divisions of Water*, which I see covers so great a *Part of the Globe's Surface*?

Clecn. The *Proportion of Water* to that of *Land*, is much about three to one; or, in other *Words*, three *Parts in four* of the whole *Surface of the Globe* are covered with *Water*, which are divided into the following *Denominations*.

(1.) *OCEANS*: These are the vast *Collections of Water* that surround the *Continents*, and receive different *Names*, according to the different *Parts of the World*, in which they lie: As the *Eastern*, or *Western Ocean*, &c. the *Indian*, or *German Ocean*, according to the *Countries* they are contiguous to.

(2.) *SEAS*: These are such *Parts of the Ocean* as lie between several *Islands*, or *Parts of Continents*, as the *Mediterranean*, the *Baltic*, the *Red* and *White Seas*, &c. Also, those great *Collections of Water*, entirely surrounded by *Land* in the *Continents*, are called *Seas*, as the *Euxine*, or *Black Sea*, the *Caspian Sea*, &c.

(3.) *LAKES*: These are any smaller *Collections of Water* on the *Land*; such as you here see on the *Globe*, viz. the *Lake of Geneva*; and particularly those fine, large, remarkable *Lakes* above the *River St. Lawrence*, in *Canada*, which are the *Basis of so great a Traffic* with the *North American Indians*.

(4.) *GULPHS*: Such *Parts of the Ocean* as are almost surrounded by *Land*. It is in *Form* analogous to a *Peninsula*; such you observe is the *Gulph of Venice*, the *Red Sea*, &c.

(5) Arms
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(5.) CREEKS: These are those narrow Parts, or Arms of the Sea, running a little Way up into the Land. If they are wide and spacious, they are then called

(6.) BAYS. Of which the most remarkable and easy to be distinguished on the Globe, are *Hudson's Bay*, in *North America*; the *Bay*, or *Gulph*, of *Mexico*; the *Bay of Biscay*; with many others.

(7.) STRAITS: These are sometimes called CHANNELS, which are those Parts of Seas that run between two Shores, or Coasts; as the *Straits of Gibraltar*, the *British Channel*, the *Straits of Magellan*, &c.

(8.) RIVERS: These are large Streams of Water, which arise from several Fountain-heads, and run towards some Lake, or Sea, where they disembody their Water. Such are the *River Thames*, in *England*; the *River Nile*, in *Egypt*; the *River St. Lawrence*; the *Danube*, and many others of very great Note; which you see diversifying the Surface of the Land, like the Veins and Arteries in the membraneous Parts of Animals.

Euphros. I shall endeavour to retain all these Distinctions and Definitions, by an Application to my Books and Globe.——I fear you have exhausted your Spirits too much at present, and shall with Pleasure dismiss you from any farther Attendance on me now.——I promise myself great Satisfaction in our next Leisure, which you tell me is to be employed in a practical Solution of the most useful geographical Problems on the Globe.

DIALOGUE XI.

*Containing the Solution of the PRINCIPAL PROBLEMS
on the TERRESTRIAL GLOBE.**

Cleonicus.

AT our last Interview, I endeavoured to prepare your Mind with every necessary Preliminary for understanding the right Use of the *Terrestrial Globe*, and as you are well acquainted with all the Circles, and the Manner of rectifying the Globe for any particular Place, we may now address ourselves immediately to the Solution of such *Problems*, as will sufficiently shew how very rational, beneficial, and entertaining, the Use of this Instrument must be, and how highly Mankind are indebted to the first Inventors of it.

Euphros. The very Pleasure of seeing the World in *one View*, is not small; it gives me such a distinct and adequate Idea of the several Parts of Land and Water, that no Maps, or other Contrivances could ever equal.—I have rectified the Globe to the Latitude of *London*, by placing $51^{\circ} 30'$ to the Horizon, which makes it ready, I presume, for the Solution of *geographical Problems*.—Pray, which is the first to begin with?

Cleon. The *First Problem* usually is, *To find the Latitude of any given Place*; and this is done by bringing the Place to the graduated Edge of the *Meridian*, where its Distance from the *Equator* will appear in Degrees. Thus, suppose I require the Latitude of *Jerusalem*, *Petersburgh*, and *Pekin*, in *China*.

* In this *Dialogue*, I shall give the Solution to *geographical Problems*, as they are performed on the *Terrestrial Globe* of the usual Form; the Examples here are accommodated to those of Mr. *Senex's* Make, particularly those of 12 and 17 Inches Diameter; but in the following *Dialogue*, the Reader will find, that the same *Problems* will receive a much more natural Solution, or Representation, from a new Construction and Apparatus of a nine Inch *Terrestrial Globe*, which is moved by Clock-work, and by which the general *Rationale* of the *Problems* pertaining to both the Globes will most evidently appear.

Euphros. This I think I can easily perform.—*Jerusalem*, I find upon the Globe, and placing it under the *Meridian*, I observe its Latitude $32^{\circ} 00'$ N. from the *Equator*.—Again, I find *Petersburgh*, in *Russia*, just in the Parallel of $60^{\circ} 00'$ —And as for *Pekin*, in *China*, when I bring that to the *Meridian*, I see it lies just under the $40^{\circ} 00'$; and in the same Manner, I could tell you the Latitude of every other Place that is marked on the Globe.—I suppose the next *Problem* will be, of Course, *To find the Longitude of a Place.*

Cleon. It is certainly so, as it is so closely connected with the Latitude,—To do this is nothing more than to observe what Degree of the *Equator* is intersected by the *Meridian*, when the given Place is brought to it.—And here I must observe to you, that the Degrees of Longitude on all Mr. *Senex's* Globes are reckoned from that *Meridian*, which passeth through *London*, (and which is usually called the *FIRST MERIDIAN*) these Degrees of Longitude are reckoned to 180° on each Side of the first *Meridian* towards the *East* and *West*.

Euphros. I understand you, and observe the first *Meridian* you speak of. When I bring *Jerusalem* to the *Meridian*, it cuts the 36th Degree of *East* Longitude on the *Equator*.—*Pekin* being brought to the *Meridian*, cuts the 116th Degree as before. After the same Manner, I observe, that any Place which lies Westward of us, being brought to the *Meridian*, both the Latitude and Longitude thereof will instantly appear. Thus, *Port-Royal*, in *Jamaica*, being placed under the Brass *Meridian*, is shewn to have $17^{\circ} 30'$ Latitude N. and its Longitude will be shewn to be $77^{\circ} 30'$ West from *London*.

Cleon. In all this you are very right.—A *Third Problem* is, *Having the Latitude and Longitude given, to find that Place on the Globe.*

Euphros. This I apprehend is nothing more than the Reverse of the foregoing Problem.—Thus, suppose I find in a *Gazetteer*, or *Table* of Latitudes and Longitudes, that *Jerusalem* was in $30^{\circ} 00'$ of North Latitude, and $36^{\circ} 00'$ of East Longitude;—then I bring the 36° of Longitude to the Edge of the general *Meridian*, and I am sure to find the City of *Jerusalem* under the 32 Degree of Latitude on the said *Meridian*.—Again, If I

know the Longitude of *Port-Royal* to be $77^{\circ} 3'$ West of *London*, and to have $17^{\circ} 30'$ of N. Latitude, then, by bringing the said Degree of Longitude to the *Meridian*, I observe the Town just under the given Latitude.

Cleon. Very good, my *Euphrosyne*.——The *Fourth Problem* is, To find the Distance between two given Places on the Globe in English Miles, as for Instance, between *London* and *Jerusalem*.——To effect this, you screw the *Quadrant* of Altitude to the Brass *Meridian*, with its Edge to $51^{\circ} 30'$, the Latitude of *London*, to which Point you bring the City of *London*, where let the Globe rest; then lay the graduated Edge of the *Quadrant* upon the given City, and you will see upon the *Quadrant* $32^{\circ} 30'$, which, by allowing 69 Miles and a half to a Degree, will amount to near 2259 Miles.

Euphros. The *Praxis* of this *Problem* is very easy, and will, at the same Time, exercise me in the little Skill I have in the Rules of *Arithmetic*.——But let me see, if I can find the Distance from *London* to *Port-Royal*.——The Globe remaining as before, I bring the Edge of the *Quadrant* to the Place, and I observe it is 69° from *London*, which multiplied by $69\frac{1}{2}$, gives $4795\frac{1}{2}$ Miles.——Thus, I can satisfy my Curiosity at any Time, in regard to the Distance of any Part of the World.——Pray, what is the *Fifth Problem*?

Cleon. To find the Point of the Compass, on which any Place bears from *London*?

Euphros. I need not give you the Trouble of shewing me how to perform this *Problem*; for it is self-evident.——For, as I see the Compass on the Horizon, when *London* is brought to the *Meridian*, and the *Quadrant* laid over any Place, it shews, at the same Time, the Point on which that Place bears from *London*.——Thus, the *Quadrant*, laid over *Port-Royal*, shews it to bear nearly on the West Point of the Compass.——If laid over *Jerusalem*, it cuts the E. S. E. Point of the Compass for the Bearing of that City.——The *Quadrant* removed to *Pekin*, in *China*, shews it to bear within a Degree or two on the N. E. Point of the Compass.——This is a Matter of no small Curiosity, which I shall practise for many other Places at my Leisure. What is the next *Problem*, *Cleonicus*?

Cleon. The Sixth Problem is, To find all those Places that have the same Latitude and Longitude with a given Place.

Euphros. This, again, is so easy at first Sight, that I wonder you learned Gentlemen should make any Problem of it.——For it is only bringing the given Place, as *Pekin*, for Instance, to the *Meridian*, and all those Places that lie under the Southern Half of the *Meridian*, must, of Course, have the same Longitude.——After this, if I turn the Globe about, it is evident, all those places which pass under the same Point of the *Meridian* with *Pekin*, must have the same Latitude.

Cleon. You will find some Problems, by and by, that you may think sufficient to exercise your geographical Genius; though by you they may be esteemed only Pastime.——The Seventh Problem is none of the most difficult, and you must let me see if you can do it without my Direction. It is, To find all those Places where it is Noon at any given Hour of the Day, in any Place proposed. For Example, you are to find in what Places of the Earth it is Noon, when it is Nine in the Morning at *London*.

Euphros. I believe you have now puzzled me.—Must not I begin with finding the Sun's Place?

Cleon. No, my *Euphrosyne*, all Problems of Time do not require the Sun's Place to be known;——but since you tacitly ask my Assistance, you will readily find it. Therefore proceed as follows:——Bring *London* to the *Meridian*, and set the Hour-Index to the given Hour IX in the Morning.——Then turn the Globe about, till the Index points to the upper XII.——Then see what Places lie under the *Meridian*; for in all those Places, it will be Noon at the given Hour.

Euphros. Well, this is a pretty Problem; let me practise it in the given Example.——I bring *London* to the *Meridian*,——set the Index to IX,——and then turning the Globe, till it points to XII, I observe, that the middle Part of *Russia*, *Circassia*, the middle Parts of *Arabia*, and *Madagascar*, all lie under the *Meridian*;

to all which Places therefore it must be Twelve o'Clock, or Noon, when it is Nine in the Morning with us.

Cleon. The Eighth Problem is but the Reverse of this, viz. when it is Noon at any one Place, to find what Hour it is at any other given Place. And therefore in the Solution of this, you will readily know how to proceed.

Euphros. Yes, surely I do ——— Supposing it Noon at London, I can tell what o'Clock it is at Jerusalem for Instance ; ——— for, if I bring London to the Meridian, and set the Hour-Index to the upper XII; then by revolving the Globe, till Jerusalem comes to the Meridian, I observe the Index point to II. 30'. But, as this is on the western Part of the Hour-Circle, it shews, that it is about Half an Hour after Two in the Afternoon ——— Again, for a second Example; if I turn the Globe till Port-Royal comes to the Meridian, the Hour-Index will point to VII. nearly, which shews, that it is Seven o'Clock with them at Jamaica, when it is Twelve at Noon with us. ——— Again, for a third Example, I shall reverse the Problem, and bring Pekin, in China, to the Meridian, where, holding it fast, I place the Hour-Index at XII; then I bring London to the Meridian, and find the Index point to Four o'Clock in the Morning ——— Such Problems as these are very entertaining. What is your Ninth Problem?

Cleon. By your last Example, you have robbed Geographers of one Problem, and, by the same Freedom, you might as well have taken that which follows, which we may now call the Ninth, viz. For any given Hour of the Day, in the Place where you are, to find the Hour in any other Place?

Euphros. This, indeed, is hardly worth considering as a separate Problem. — For, when it is Five o'Clock with us, in the Afternoon, if I would know what o'Clock it is then in Port-Royal in Jamaica, I need only bring London to the Meridian. — Set the Hour-Index to V, on the West Side; — then revolving the Globe, till Port-Royal comes to the Meridian, the Index points nearly to XII. — This shews, Cleonicus, that when we sit down to Tea at Six, they begin to think of their Dianer at Jamaica.

Cleon. These Problems, I see, you are sufficiently ready at.—I believe the Tenth will be very agreeable to you, which is, *To find all those Places in the Torrid Zone, to which the Sun is vertical for any given Day.*

Euphros. In the Solution of this Problem, I foresee your Direction will be necessary. Please to say how I must proceed.

Cleon. Let the given Day be the 20th of April; opposite to which Day, upon the Calendar in the Horizon, you will see the first Degree of *Taurus* in the *Ecliptic* placed by it, which shews the same Degree in the *Ecliptic* on the Globe, is the Place of the Sun for that Time.—Therefore, I bring the Sun's Place, or Beginning of *Taurus*, to the *Meridian*, which it intersects in the 11th Degree: Then turning the Globe quite round, you observe all those Places upon the Surface, which pass under the said 11th Degree of the *Meridian*, are the Places required, or those which have the Sun passing over their Heads for that Day.

Euphros. This Problem is more curious than difficult; by which I learn, that every Place in the *Torrid Zone*, whose Latitude is equal to the Sun's Declination, will find him in their Zenith at Noon.—What is your Eleventh Problem, *Cleonicus*?

Cleon. To find the Midsummer-days for any given Place in the *Torrid Zone*. This Problem I shall shew you the Solution of as follows:—Let these two Days be required for *Port-Royal*, in *Jamaica*,—Then, I bring that Town to the *Meridian*, and observe what Degree it cuts, which is $17^{\circ} 30'$.—Then, turning the Globe, I observe what Part of the *Ecliptic*, next to *Aries*, touches that very Point of the *Meridian*, and find it to be the 20° of *Taurus* 8.—This Degree I look for on the Horizon, and find against it, the 10th of *May*, which therefore is their first Midsummer-Day.—Then, I turn the Globe farther about, till some Part of the second Quadrant of the *Ecliptic* comes under the same Part of the *Meridian*, which I find to be the 10th Degree of *Leo* Ω .—Then, against that Degree of the *Ecliptic* in the Horizon, I find corresponding to the 3d Day of *August*, which therefore is their second Midsummer-Day.

Euphros. I see, by the Manner of your Solution, that I shall find but little Difficulty in performing the same Thing for any other Place.—What *Problem* succeeds to this?

Cleon. The *Twelfth Problem* finds all those Places in the North Frigid Zone, where the Sun begins to shine, constantly, or without setting, on any given Day.—The Solution is in this Manner.—Let the given Day be the 26th of April.—Then, the Sun's Place for that Day, will be in $6^{\circ} 00'$ of *Taurus* in the *Ecliptic* on the Horizon.—Which Place I find in the *Ecliptic* on the Globe, and bring it to the *Meridian*, which shews the *Declination* of the Sun for that Day to be $13^{\circ} 00'$ —Then it is evident, that all those Places which are the same Number of Degrees from the Pole, or which are in the 77th Degree of North Latitude, are the Places required.

Euphros. I can plainly see the Reason of that, as the Circle of constant Illumination must necessarily be the same Distance from the Pole, as is equal to the Sun's *Declination*.

Cleon. The *Thirteenth Problem* is somewhat a-kin to the foregoing.—It consists in finding on what Day the Sun begins to shine constantly, or without Setting, on any given Place in the Frigid Zone, and how long it continues so to do.—To solve which, let the Time required be for Point Look-out, or the southernmost Part of Greenland.—Then first, I find the Latitude of that Cape, which is $77^{\circ} 00'$.—Secondly, I rectify the Globe to the Latitude of the Place.—Thirdly, turning the Globe about, I observe what Point in the first Quarter of the *Ecliptic* coincides with the North Point of the Horizon, which, I observe to be the sixth Degree of *Taurus*.—Fourthly, I seek the same Degree of *Taurus* in the *Ecliptic* on the Horizon, and find against it in the Calendar, the 26th Day of April, which satisfies the first Part of the Problem—Fifthly, I turn the Globe back again, to observe what Point, in the second Quarter of the *Ecliptic*, exactly coincides with the North Point in the Horizon, and I find it to be the $24^{\circ} 00'$ of *Leo*.—Sixthly, I seek the said Degree in the *Ecliptic* on the Horizon, and find it answers to the 17th Day of August.

August.—Therefore, from the 26th of *April* to the 17th of *August*, the Sun shines constantly on the Inhabitants of the most southern Parts of *Greenland*.

Euphros. By the particular and gradual Process you have used in the Solution of this Problem, I find, not only the Method for any other of the like Kind is very easy, but, also, the *Rationale* thereof is very evident; and therefore you may proceed more concisely in what other Problems remain.

Cleon. The remaining Problems are but few; that, which you may reckon the Fourteenth, is *To find the Place over which the Sun is vertical on any given Day and Hour.*—In order to this, you are to find the Sun's Place in the *Ecliptic*, and bring it to the *Meridian*, and mark the Degree of Declination for the given Hour.—After this, find those Places which have the Sun in the *Meridian* at that Moment;—and, among them, that particular Place which lies under the Degree of the Sun's Declination, is the Place desired.

Euphros. As you have given me the Clue, I can proceed through the Whole of this Problem without your farther Instruction, at least I will attempt it.—I therefore suppose it was required, to find the Place to which the Sun is vertical on the 20th of *April*, at Nine at Night precisely.—The Sun's Place, at that Time, I find on the *Horizon* of the *Globe* to be in the first Degree of *Taurus*;—this I bring to the *Meridian*, and there observe his Declination to be about $10^{\circ} 30'$.—Then will all those Places, that pass under that Degree, have the Sun vertical to them that Day.—In the last Place, I find all those Places where it is Noon at Nine o'Clock at Night on that Day:—And amongst them, that which lies under $10^{\circ} 30'$ of the *Meridian* is the Place required; and this I find is in the *Pacific Ocean*, or *Great South Sea*, and as it accidentally happens, in the very Tract of Lord *Anson's* Voyage from *Aquapulco* to *China*, which has 135° West Longitude from *London*.

Cleon. It is with Pleasure I see how great a Mistress you are of geographical Solutions ———I believe it will not now be in my Power to mention any future Problem, that will be too difficult for you. However, the Fifteenth will still extend your Ideas of this Kind, which

is,

is, *To find, for any given Day and Hour, those Places wherein the Sun is then Rising, or Setting, or in the Meridian; also, those Places which are enlightened, and those which are not; and for an Example, you may take the same Day and Hour of the last Problem, viz. April the 20th at Nine at Night.*

Euphros. I fear what you say to encourage me, will rather tend to dispirit me; for, if I may have the World for my Pains, I know not which Way to go about this, which you think so easy a Problem.—

Cleon. You have no Reason to be disheartened, it is but a Trifle that you want to recollect, to make the Problem as clear as the Day ——— For only find the Place to which the Sun is vertical at the given Hour, (which you know how to do by the last Problem) and bring the same to the Meridian, and elevate the Pole to the Latitude of the Place, then all the rest will be easy.

Euphros. This I will do. ——— The Latitude of the Place is $10^{\circ} 30'$: ——— therefore I elevate the Pole to the same Number of Degrees above the Horizon, ——— and thence, since the Sun is vertical to the middle Point of the Hemisphere about the Horizon, it is evident, (1.) That all those Places which are in the western Semi-circle of the Horizon see the *Sun Rising*, as they are $90^{\circ} 00'$ distant from the Brass Meridian. (2.) For the same Reason, those who are in the eastern Semi-circle see the *Sun Setting*. (3.) And to those who are under the Meridian it is XII o'Clock, or *Noon*. (4.) and lastly, All Places above the Horizon are enlightened by the Sun, and to them it is *Day*; and all that are below it, of Course, are in Darkness, or *Night* ——— Upon the Whole, I think this a very curious and extensive Problem.

Cleon. It is as useful as curious, since, by Means thereof, you readily solve the Sixteenth Problem, which is, *To exhibit, in a general Manner, all those Places on the Earth to which a solar, or lunar Eclipse is visible, when the Time thereof is known.* ——— If you remember, some Time since I was mentioning to you, a very great Eclipse of the Sun, which will happen the 1st of April, 1764: This I propose to you as an Example. ——— This Eclipse begins at IX, and ends at XII nearly.

Euphrosi. By this I know what my Task will be,—— for, in the first Place, I must find the Place to which the Sun is vertical at Half an Hour past X on the first Day of *April*, that being the Middle of the Eclipse:——this I find to be near the Middle of the Continent of *Arabia*:——to which, when I rectify the Globe, I observe all the midland Parts of *Norway*, *Poland*, *Turkey* in *Europe*, and the vast Continent of *Africa*, lie under the general Meridian, and observe the Middle of the Eclipse at Noon.——Also, all the Hemisphere above the Horizon shews me all those Parts of the World, in which the Eclipse can be visible. Therefore I am convinced, it will be seen in all Parts of *Europe* and *Africa*, as also all *Asia*, except the eastern Part of *Tartary*, *China*, &c. But the eastern Parts of *South-America* only can see any Thing of this Eclipse.—— If I cast my Eye on the western Part of the Hemisphere, I observe the Countries in *North* and *South-America*, which lie upon the Horizon, to be those People who see the Sun rising at the Middle of the Eclipse.—— And in the eastern Part of the Horizon, the several Countries upon the Horizon there view the Sun Setting at the same Time.——Again, if I bring *London* to the Meridian, and place the Hour Index to IX in the Morning, and then revolve the Globe till the Index points to XII, I view all those Countries under the Meridian, where the Eclipse begins at Noon; particularly at *Madagascar*, the inland Parts of *Arabia*, the *Persian* Gulph, the *Caspian* Sea, and of all the eastern Part of *Russia* in *Europe*; but scarce any inhabited Part of the Earth view the Beginning of the Eclipse at Sun-Rising, since the western Horizon lies almost wholly on the *Great Atlantic*, and *Southern Oceans*. On the other Hand, a few of the eastern Islands only of *Asia* can see the Beginning of the Eclipse at Sun Set.—In the last Place, I bring *London* to the Meridian, and place the Index to the upper XII, which gives me a View of all those Places under the Meridian, who view the dark Disk of the Moon going off from the Sun at XII o'Clock. On the western Horizon, I view the Countries where the Sun is rising, when the Eclipse ends: and in the eastern Part of the Horizon I see in what Parts of the

the World, the Sun appears to set, with its entire enlightened Disk.——Are not these the general Phenomena of this Eclipse, as represented on the Globe, *Cleonicus*?

Cleon. They are, my *Euphrosyne*, and very scientifically represented; I could not have done it better myself.—I see you want no more of my Instructions, in regard to the Use of the Terrestrial Globe; for though there may be a great Diversity of Problems proposed, yet they will all become very easy in Practice, and their general *Rationale* will appear to any one who has been exercised in those which I have selected for your Institution in this Science, for they are all of them of a fundamental and general Nature.—If any Thing farther remains, there is yet a few Minutes to spare; therefore be free to ask of me any Thing you think proper, relative to the Use of this Globe, while it is before us.

Euphros. I see but one Thing more on the Globe to trouble you with, and that is, that long Slip of Paper, which is pasted on the Globe, across the Equator, containing the Calendar, or Months and Days of the Year: I should be glad to know the Use of that, as you have said Nothing hitherto about it.

Cleon. It is very proper you should be acquainted with the Use of it, as it is a curious Appendix to the Globe, and the Invention of the ingenious Mr. Harris, Author of *A Treatise on the Globes*. It has been lately affixed to the Globe; it may be called a *General Rectifier* (though it is otherwise called the *Analemma*.) The Use of it is thus, you bring it to the General Meridian, and there holding the Globe fast, set the Hour-Index to XII; then (1.) at one View, you observe on that Paper the Sun's Declination for any particular Day in the Year, whether North or South. (2.) You rectify the Globe to the Latitude of any Place, and then bringing the Rectifier to the eastern Part of the Horizon, you place any given Day of the Month to the Edge of the Horizon, and you see the Point of the Compass on which the Sun, that Day, rises; and consequently, the Amplitude of the Sun is instantly known: The Time of its Rising is also shewn by the Index of the Hour Circle, and consequently the Length of Day and Night.—And since these

these Things are shewn, as it were, by Inspection, for one whole Year, it gives a Summary of the Problems relative to the Sun, and in some Measure supplies the Use of the Celestial Globe.

Euphros. This I think is a great Curiosity indeed.—I could not have thought so many Problems of Importance could have resulted from so small a Slip of Paper.—But I shall trouble you no farther at present, with these Things, your Lecture, at this Time, having been of an uncommon Length.

DIALOGUE XII.

The DESCRIPTION and USE of a New APPARATUS to the TERRESTRIAL GLOBE, by which the true diurnal MOTION of the EARTH on its Axis, the apparent annual MOTION of the SUN in the Ecliptic, the various Phænomena of DAYS and NIGHTS, the SEASONS of the Year, and of a Solar ECLIPSE are exhibited by New MACHINERY.

Euphrosyne.

WELL, *Cleonicus*, I am sure I have lost no Time, since our last Interview, in making myself perfect in the Use of the Globes.—I have practised every Problem over and over again, on both the Globes, and now I may say, with the rich Man in the Gospel, *What lack I yet?*

Cleon. Why, to answer according to your own Stile, though you have been indeed busy about many Things, yet *one Thing is needful*:—You have been long engaged in learning how the Phænomena of Nature may be artificially represented by Globes, and in this you find great Assistance from the Labours of many ingenious Men; but with little Attention, it will appear, that those Things will admit of a much more natural Representation with a little Contrivance and small Expence of Machinery; and you will readily allow, that the more natural any Phænomenon can be shewn, the more Satisfaction

faction and greater Instruction it must give to every inquisitive Mind.

Euphros. No one can doubt the Truth of that, and I see you have provided here a beautiful Machine for that Purpose; and I flatter myself, I shall have great Pleasure in being instructed in the Use of it.

Cleon. To say the Truth, I have employed my utmost Skill to contrive it for your Instruction; for though there have been two or three Inventions of this Kind already proposed to the Public, yet I think them by no Means so simple and elegant as suits with the Nature of the Design, and worthy the delicate Genius of your Sex.

Euphros. Compliments but ill suit with philosophical Instructions; therefore, without any farther Ceremony, explain to me the Use of the Machine, for I am impatient to know it.

Cleon. I will oblige you in this, and every Thing else I can, to the utmost of my Power.

First then, By opening a Door in the Side of the Machine, you observe a Train of Wheel-work, put in Motion in the same Manner as that of a Spring-Clock. This may be called, the *Primum Mobile* of the Machine.

Secondly, On the upper Part of the Machine, you observe a Terrestrial Globe is placed, which is moveable on its Axis by the Hand, yet so as to remain in any Position where it is placed.

Thirdly, by the Machinery within, a Motion is communicated to the Globe, about its Axis, by Means of that Wheel which you see on the Top of the Box, and fixed to the Axis of the Globe. This is the diurnal Motion of the Globe, performed in the same Time with that of the natural Globe, *viz.* in 24 Hours.

Fourthly, On the Surface of the Globe, you observe an artificial moveable Horizon, by which the Globe may be rectified to the Latitude of any given Place.

Fifthly, The Axis of the Globe makes an Angle with the Axis of the *Ecliptic* of $23^{\circ} 30'$.

Sixthly, The Globe has another Motion communicated to it, by which the Plane of the *Ecliptic* is gradually moved round in the Space of one Year, or 365 Days.

Seventhly, In Consequence of this, a Brass Ball representing the Sun, placed on a Stem upon one Side of the Machine,

Machine, and just in the Plane of the Ecliptic, will appear to move through every Sign and Degree of the Ecliptic in the Space of twelve Months, just as the real Sun appears to move in the Heavens.

Eighthly, A Brass Circle is placed about the Globe at the Distance of 90° every Way from the Sun, which may be called, the *Solar Horizon*, or *Circle of Illumination*, because it constantly divides the Globe into the enlightened and dark Hemispheres.

Ninthly, On the Wheel affixed to the Axis, you observe a moveable Hour Circle, and a fixed Index, by which Means the Time of any Phænomenon is shewn, and the Globe rectified in regard thereto.

Tenthly, By removing the Sun, I place these two Brass Arms to the Sides of the Machine, which, by Means of Screws, are moveable up and down, so that the long Piece of Brass, you see moveable upon the Ends of each, may be placed either horizontally, that is, parallel to the Plane of the Ecliptic, or inclined thereto, in any Angle less than 6° . So that it may be placed parallel, at any Time, to the Path of the Moon.

Eleventhly, To the middle Part of this transverse Piece is fixed another, at right Angles, with Spring-Sockets, through which slides a long Slip of Brass, on the Top of which is fixed a dark Circle, representing the Moon's penumbral Shadow, at the Surface of the Earth, in a Solar Eclipse; and in such Proportion to the Globe, as the real *Penumbra* of the Moon has to the Globe of the Earth.

Twelfthly, The Slip of Brass which carries the lunar Shadow is divided, from a certain Point each Way, into a Scale of Minutes, by which Means, in any Eclipse, the nearest Distance between the Center of the *Penumbra*, and the Earth's Disk, or the Latitude of the Moon in an Eclipse at the Time of a true Conjunction, may be truly expressed, and thereby the lunar *Penumbra* properly adjusted to the Disk of the Earth, and its true Passage over it shewn in that Eclipse.

Thirteenthly, The lower Part of the transverse Piece is divided into Teeth, adapted to a small Pinion that you see in the Side of the Machine, by which Means this Piece, when the Machine is in Motion, carries the penumbral Shadow over the Earth's Disk, with the proper Velocity of

of Motion which the Moon really has at that Time in her Orbit, or which the penumbral Shadow really has on the Disk of the Earth.

Fourteenthly, But as the Moon's Motion is sometimes quicker, and sometimes slower, if we would be very accurate, there should be three of those transverse Pieces, containing each a different Number of Teeth of the same Length, and fitted to express the greatest, mean, and least Velocity of the Moon's Motion.

Fifteenthly, The Machinery is so contrived, that the diurnal Motion of the Earth, and annual Motion of the Sun may be performed in a short Space of Time, viz. The annual Motion in six Hours, and the diurnal in nearly one Minute. — And now, my *Euphrosyne*, you are prepared for viewing the great Phænomena of Nature, just as they happen in the Course of Things, or otherwise, at Pleasure *.

* *An EXPLANATION of the MACHINE.*

ABDF, Is the Body of the Machine.

C, The Center of the Globe.

ÆQ, Equator.

EL, The Ecliptic.

NS, The Axis of the Globe.

GH, The transverse Piece, with Teeth.

IK, The circular Arms, on which it moves.

O, The Pinion which moves it.

RS, The fixed perpendicular Piece.

MS, The Sockets upon the same.

CP, The long graduated Slip of Brass, carrying

NV, The penumbral Shadow of the Moon.

TU, The Circle of Illumination.

W, The Stem, or Foot thereof.

X, The Part on which the Globe rests.

Y, The Part on which the Globe is supported.

Z, The horary Circle, which gives Motion to the Globe.

In the Print we have exhibited the Apparatus for representing the *Solar Eclipse*, April 1, A. D. 1764, as being the most remarkable that will happen for many Years to come. We have not represented the *Sun*, the moveable *Horizon*, *Crepuscular Circle*, &c. to avoid Confusion, especially as they are easily supplied by the Imagination, and so particularly described in their Uses above.

Euphros. In regard to the Use of this new constructed Globe, I must be entirely passive, as I know not yet which Way to go about solving any one Problem; but shall be very glad to see those natural Phænomena arise from the Direction of your own Hand.

Cleon. I will shew them to you in their natural Order; and, first, you are to observe, that since the Pole of the Ecliptic is the highest Point of the real Globe of the Earth, as it revolves about the Sun in its annual Orbit, so the same Pole of the Ecliptic must always be the highest Point, and therefore, what we may call the *Zenith* of this artificial Globe, the nether Pole of the Ecliptic being the *Nadir*.

Euphros. This I plainly see; and in Consequence of which, the Ecliptic may be called the Horizon; at least, I see it parallel with the Horizon of the common Globe, and will always remain so.

Cleon. Your Remark is just.—Secondly, to rectify this Globe, I fix the Ball, representing the Sun in the Plane of the Ecliptic, on its Stem, at a small Distance from the Globe.—Then, by turning the Winch, I cause the Ecliptic Circle to move round; so that any Part which the Sun occupies at any Time, may be placed against the Brass Ball, or artificial Sun.—Thus, for Instance, on the first Day of *April* the Sun being in the twelfth Degree of *Aries*, I bring that Point exactly against the Ball; and thus the Globe is rectified for that Day of the Year.

Euphros. This is a different Rectification of the Globe from what you shewed me before; but I suppose it is such as corresponds to the respective Situation of the Sun, and the Earth in its Orbit for that particular Day.

Cleon. It does so very exactly; for the Earth being in the twelfth Degree of *Libra*, if we look at the Sun in the Center, it must necessarily appear in the opposite Point, or twelfth Degree of *Aries*, as you very well know.—Thirdly, I put the Machinery in Motion, and, in the Space of nearly one Minute, you see the Earth revolve once round upon its Axis with an equable Motion, which exhibits to you a natural Idea of the Manner in which the real Earth does turn upon its Axis, as it proceeds in its Orbit about the Sun.

Euphros. This is a very curious Representation, indeed, of the Earth's diurnal Motion ; and I observe the Index below points out the several Hours of the Day, and Night, on the horary Circle in its Revolution.

Cleon. You will next observe, my *Euphrosyne*, that when the Sun again comes into the Plane of the Ecliptic, after one Rotation of the Earth about its Axis, that it is found to possess the next, or thirteenth Degree of the Ecliptic ; so that you are convinced of the fourth Phænomenon by ocular Demonstration, viz. That in the Space of one natural Day, the Sun has an apparent Motion in the Ecliptic of one Degree nearly.

Euphros. This I observe with Pleasure, as it is very natural to see how the apparent Motion of the Sun, in this little Globe, answers to that of the real Sun in the Heavens:—But as there are 365 Days in the Year, and only 360 Degrees in the Ecliptic, the apparent Motion of the Sun, at a Mean, cannot be quite one whole Degree in a Day ; but the Difference is too small to be insisted on here.

Cleon. It is, indeed, very small for one Day ; but in the Space of the whole Year you will find every Part of the Ecliptic will be passed over by the Sun.—The fifth Phænomenon you will next observe, is the Passage of that Part of the Earth's Surface under the Sun, to the Inhabitants of which the Sun is successively vertical on that Day.

Euphros. This appears extremely natural, indeed ; I plainly see, that for the first Day of *April* all the midland Parts of *Africa*, the *Indian Sea*, the *Isle of Ceylon*, the Kingdom of *Malacca*, the *Philippine Islands*, the vast Tract of Ocean between them and *America*, the large Continent of *South America*, called *Terra Firma*, &c. all pass under the Sun, and therefore view him in their Zenith.—I must needs own, this Representation far exceeds that for the same Purpose on the common Globe.

Cleon. The sixth Phænomenon is the variable Length of Days and Nights, according to the different Times of the Year, which offers itself to the View here, just as it does in Nature ; for when I bring the Meridian of any Place to pass through the Sun, I then move the Hour of the Noon-Tide XII to the Index, and rectify the Moon's Horizon by the Latitude of that Place ; for the Globe, in

II Motion,

Motion, naturally shews you the Length of the Day and Night, at any given Time of the Year.

Euphros. I apprehend it must be so: But an Example will still make it clear, which, I think, I am able to perform myself.—I shall take our capital City, *London*, for the Place; and therefore rectify the moveable Horizon by fixing it at $51^{\circ} 30'$ from the North Pole, by the general Meridian drawn on the Globe:—And now, I will first adjust the Sun to the Beginning of the Ecliptic, by turning the Globe about till the Vernal Equinox is right against it:—Then, please to put the Machine in Motion.

Cleon. It is done.

Euphros. And very plainly I observe, that at the End of six Hours the Western Part of the Horizon is against the Center of the Sun:—That in twelve Hours more, the Eastern Part of the Horizon is upon the Sun:—And after another six Hours, the Equinox returns to the Sun, and plainly shews me the Length of the Day and Night is the same on that Day of the Year.—Also, I see the Sun naturally setting, or apparently passing below the Western Part of the Horizon at Six in the Evening:—and rising above the Horizon at Six in the Morning, just at the Point due East.—All this I can easily see will follow from the Motion of the Earth, carrying the Horizon of *London* along with it, over the Body or Disk of the Sun.

Cleon. And one Thing farther you will take Notice of, a seventh Phænomenon, which will more illustrate this Doctrine, which is, the *Circle of Illumination* fixed to the Machine, and surrounding the Globe in such a Manner, as to divide it into the enlightened and dark Hemispheres. This Circle may, with some Propriety, be called the solar Horizon, as it is every where exactly 90° distant from the Sun.

Euphros. I readily see what Consequences will attend this Observation:—Because it must necessarily happen from hence, that when the Horizon of any Place is upon the Sun, the Place itself will be under the Circle of Illumination, and therefore, just entering into the darkened Hemisphere.—The Reason, therefore, of Day and Night, and all their Variations is, from hence, extremely obvious, and more so, by much, than in the Orrery itself.

Cleon. You cannot be too well apprized of the Nature of this grand Phænomenon; and therefore it will be proper to repeat the Experiment for the longest Day in the Year in the Latitude of *London*, which will present you with a View of the greatest Inequality of Days and Nights that can happen here.

Euphros. This, I presume, I can easily do, by moving the first Degree of *Cancer* to the Sun, and then turn the Globe on its Axis till the Sun comes to the Meridian of *London*,—where letting it rest, I turn the Hour Circle till the Meridian XII is at the Index:—Then giving Motion to the Machine,—I see the Globe revolves in such a Manner, that the Tropic of *Cancer* constantly passes under the Sun, from West to East, till at Length the Western Horizon comes upon the Sun:—At the same Time I observe the City of *London* is under the *Circle of Illumination*, and goes into the darkened Hemisphere at the same Moment of Time that the Sun is seen below the Horizon.—When this happens, the Index points to VIII o'Clock, and somewhat more.—Again, the Globe, continuing in Motion, carries the Island of *Great Britain* through the darkened Hemisphere, till at Length it appears on the other Side of the *Circle of Illumination*, and the Eastern Part of the Horizon revolves to the Sun;—At which Moment of Time I see the Index pointing nearly to the Hour of IV in the Morning:—So that from hence it is evident, that the longest Day with us is a little more than XVI Hours, and the shortest Night nearly VIII, and therefore but half as long as the Day:—The Manner in which these Things appear so nicely according with Nature itself, redoubles the Pleasure of Instruction.—But what is that small Circle, which I see every where at an equal Distance from the moveable Horizon?

Cleon. That may be called the *Crepuscular Circle*, or *Circle of Twilight*. It is placed at $18^{\circ} 00'$ below the Horizon, because, till the Sun has descended so far, some of his Beams will be refracted by the Atmosphere, and make a Twilight, or a decreasing Mean between Day and Night: But when the Sun has reached that Circle, we find it dark Night; and, therefore, as the Globe revolves, at the same Time you observe the Time of the Beginning of Day and Night, you see also the *Beginning*, *Duration*,
and

and *End of Twilight*, which is the eighth Phænomenon in this Machinery.

Euphros. Well, this is a Curiosity over and above what I expected; a Piece of Knowledge that does not please me a little: for, though I had some indirect and faint Ideas before, my Notions of it are vastly enlarged and improved by this natural Representation.—And what delights me very much is, that in the last Example of the longest Day, I see there can be no dark Night at all; since the Sun, at Midnight, is not by many Degrees so far below the Horizon of *London* as is the *Circle of Twilight*.—Nor indeed, for many Days before and after the longest Day, the Depression of the Sun, at Midnight, will not be so great as the Distance of that *Crepuscular Circle* from the Horizon; and that, for that Space of Time, there will be *no dark Night*, which there must be, more or less, at all other Times of the Year.

Cleon. At your Leisure, you may practise this Problem for the shortest Day, in the same Manner as for the longest; and likewise, for the Times of the Beginning and End of Twilight at any Time of the Year. What I must next observe is, the ninth Phænomenon, which is of the greatest Importance of all, *viz.* The various SEASONS of the Year:—For, by what we have already seen, you learn, (1st,) That when the Sun, in its apparent Motion, possesses the Beginning of the Ecliptic, or first Point of *Aries*, then also the Poles of the World appear under the *Circle of Illumination*, and then the Days and Nights are not only equal, but the Sun being at an equal Distance from either Pole, his Light and Heat is then of a Mean Degree, and makes that delightful Season which we call the SPRING. (2dly.) As the Sun advances in its annual Course gradually towards *Cancer*, the North Pole, by degrees, is brought still farther into the enlightened Hemisphere, till, at last, when the Sun arrives to the first Degree of *Cancer*, the North Pole is then $23^{\circ} 30'$ within the illumined Hemisphere, or by so much nearer the Sun than it was before; and consequently its Light and Heat will now be the greatest of all, in all the Northern Latitudes, as well as the Days the longest; and therefore you see the Nature

of the Season we call SUMMER, demonstrably plain, (3dly,) The Globe continuing in Motion, the Sun appears to advance towards *Libra*; and the North Pole retreats, by degrees, and gets a second Time under the *Circle of Illumination*:—At that Instant the Sun arrives at *Libra*, and then it causes the *autumnal* SEASON. (4thly,) The Motions of the Globe continuing, you see the Sun gradually advance, from Day to Day, towards the Beginning of *Capricorn*; and the North Pole going farther and farther into the darkened Hemisphere, till, at Length, when the Sun comes to the first Scruple of *Capricorn*, the North Pole will be then $23^{\circ} 30'$ from the *Circle of Illumination* in the darkened Hemisphere, and that of Course, in this Position of the Globe, the Days will not only be the shortest, but the Light and Heat of the Sun will be the least it ever can be in Northern Latitude, and therefore makes the *Winter* SEASON.—Hence, in a short Time, you see all the Succession of Seasons, with all their Variety of Incidents, in the Course of a whole Year.

Euphros. This is not only a compendious, but a beautiful View of Nature's great Events, resulting from the most simple Causes.—Not only the Seasons, and different Length of Days and Nights, but likewise many other curious Subjects offer themselves to my View, in this Speculation of a Globe in Motion:—I see the Parts of the Earth, or Circum-polar Regions, alternately, wholly enlightened, or wholly in the Dark, at opposite Times of the Year.—I see when the Sun begins to shine without setting, and to set without shining any more to the different Inhabitants within the Polar Circle:—I observe, how naturally all the different Parts of the Torrid Zone come under the perpendicular Beams of the Sun, in the Course of a Year.—But I shall no longer detain you with these common Subjects,——There is yet an Apparatus remaining, which, I see by the Form of it, has Relation to the Nature of Eclipses; pray, am I, at present, to learn the Use of that?

Gleop. By all Means, it being the principal Part of the Design of this Construction, to give you a more natural View of a Solar Eclipse, and the Manner in which

which it happens, than by any Contrivance of the common Globes, Orreries, &c. especially what relates to an Explication of the particular Phases thereof; for, to answer such Purposes in the best Manner, you ought to know in what Manner the Shadow of the Moon goes over the Surface of the Earth in the Time of the Eclipse. Although I have formerly illustrated this, by a Copper-plate Print, in a general Way, * yet that will by no Means suffice for a full and adequate Notion of this Matter. It was there, indeed, shewn, what was the *total*, and what the penumbral Shadow of the Moon; but it still required the Surface of a Globe, to shew the Proportion of the dark and penumbral Shadow, when compared therewith; also what is the particular Course over, and Figure of the Shadow upon the Surface of the said Globe, so that it may have the same Appearance as if you was actually to see it on the Surface of the Earth itself.—The Astronomers have Methods whereby they can, at all Times, ascertain the true Dimensions of the Moon's Shadow at the Surface of the Earth, and, consequently, can assign the Proportion it bears to the Earth's Surface: Therefore, whatever the Size of the Globe you make Use of may be, we can immediately adapt a Shadow to it, by cutting out a circular Piece of black Crape, which shall bear the required Proportion to the Surface of the Globe. This Crape will denote the penumbral Shadow.—In the Center of this Crape we can fix one of your small Patches, to represent the dark Shadow of the Moon, in a proper Proportion to the penumbral Shadow; and here, let me tell you, it is much more properly applied than when it is placed on your own Face, to eclipse some of the natural Beauty thereof.—In the next Place, the Inclination of the Moon's Orbit to the Plane of the Ecliptic, is at all Times known; and therefore the Latitude of the Moon, or its perpendicular Distance from the Ecliptic, is known at the Time of any given Eclipse, and, consequently, the Path of the Center of the Shadow may be thereby assigned on the Surface of the Globe:—Consequently, the Time when the Shadow

* See Plate XVIII. Page 150. Vol. I.

first enters on the Disk of the Earth, or Surface of the Globe, and also the Time when it goes off; and therefore, the Beginning, the Middle, and End of the Eclipse, with the Quantity thereof, may easily be determined and represented by this Machinery.

Euphros. I must confess that, till you have put your ecliptic Apparatus in Order, and applied it to the Machine, I cannot have so clear an Idea of the Design of it as I then may; for, I presume, the Use of each particular Part will then more fully appear.

Cleon. It will so:—But before we can proceed any farther in this Speculation, we must adjourn to a Sun-shiny Morning, when we can view the various Phases of a Solar Eclipse to the best Advantage; and till then you may ruminate on the Subjects that have, at present, passed between us, and render yourself more perfect in the Uses of the Globe each different Way.

DIALOGUE XIII.

On the Use of the New Apparatus to the TERRESTRIAL GLOBE, in explaining the Nature and various Phænomena of SOLAR ECLIPSES, exemplified in that which was to happen in 1764.

Euphrosyne.

I WAS scarcely ever more impatient for any Event, than of the Sun-shiny Morning, to which you adjourned. And now the wished-for Hour is come, the Air is serene and clear, and we have the fairest Prospect of an entire fine Day: And you will be mindful of the old Proverb, *To make Hay while the Sun shines*, and apply the solar Apparatus as speedily as you can, and thereby give me the Pleasure of seeing Nature anticipated in that future great Phænomenon.

Cleon. I will do so; and therefore, first, I apply the two circular Arms to the Side of the Box, which are moveable up and down, at Pleasure; and on these Arms, the long transverse sliding Piece, with Teeth on the lower

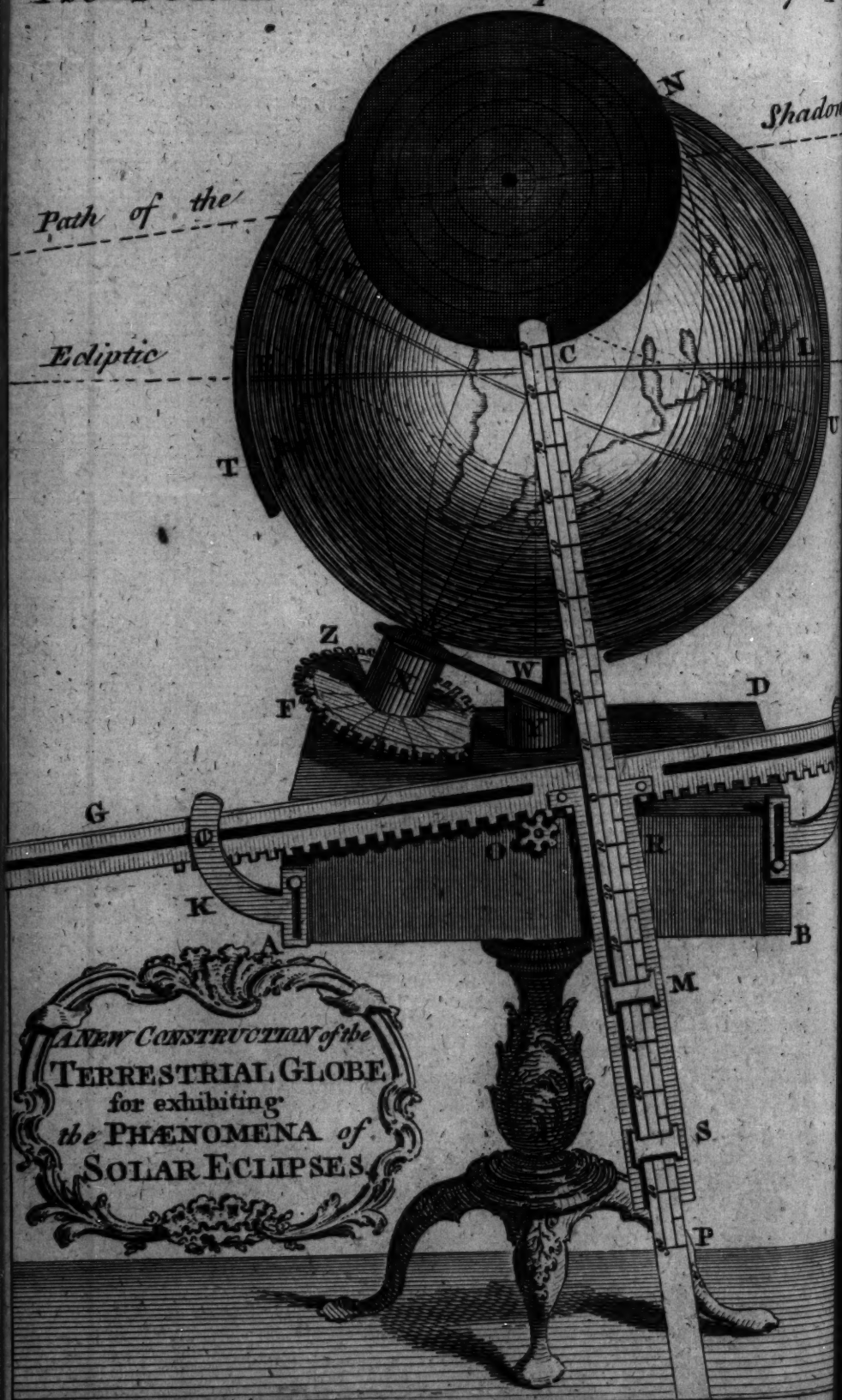
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The SOLAR ECLIPSE April 1st A.D. 1764



A NEW CONSTRUCTION of the
TERRESTRIAL GLOBE
for exhibiting
the PHENOMENA of
SOLAR ECLIPSES.

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lower Part, to the Number of Eighty; to the middle Part of this Piece I apply the Crape, or Shadow of the Moon, placed on the Top of a long Stem, or Slip of Brass, before described, and lowering one of the Brass Arms, and raising the other, I fix the Sliding-piece exactly parallel to the Orbit of the Moon, which is done by the Divisions on the Sliding-part of the Arms; then I move the Arm which carries the Shadow up, or down, in the Sockets, till such Time the Number which expresses the Latitude of the Moon from the Ecliptic, in the Middle of the Eclipse, touches the upper Socket, and there screw it fast. — A Motion is then communicated to the Slider by a small Pinion, which you see on the Outside of the Box, working in the Teeth of the Slider; and as twelve Teeth in the Slider answers to one Hour's Motion, there will be six Hours and a half Motion upon the whole, if required, which is somewhat more than the Time of any generally Solar Eclipse. — And now, to make every Thing clear and plain, by Example, I shall give you a Representation of that remarkable Solar Eclipse that will happen on the 1st Day of April in the Year 1764.

Euphros. That I understand, by what you have said, is the largest Eclipse we are to expect for many Years to come, and therefore a Representation of it, in your new, and natural Method, must certainly be very agreeable.

Gleon. That you may have the clearest Idea of this Matter, you are to suppose yourself, at the Time of the Eclipse, translated to the Moon; and from thence to view her Shadow passing over the Surface of the Earth, which Surface, or Disk of the Earth, will appear sixteen Times as large, to your Eye placed there, as the full Moon appears to you here; and all the enlightened Surface of the Earth will, in such a Case, be turned directly to your Eye in the Moon; and you would, in that Case, see the penumbral Shadow of the Moon gradually coming on, and traversing over the upper, or northern Parts of the Earth's enlightened Disk, together with the dark central Spot in the Middle. — This Appearance of the Earth's Disk, as I said before, may be represented by a Globe of any Size, and the Crape to represent the penumbral

penumbral Shadow, with the Patch in the Middle to represent the dark Shadow, being proportioned thereto, will, when the Machine is in Motion, exhibit to you very nearly the same Appearance as you would observe from the Moon.—Therefore, in the first Place, as it is known by Calculation that this Eclipse will happen when the Sun is in the twelfth Degree of *Aries*, I adjust the Globe so, that that Point of the Ecliptic may be just in the Middle of the enlightened Hemisphere, or every Way 90° from the Circle of Illumination, and just at that Point of the Ecliptic I place the artificial Sun: Then I bring the Meridian of *London* to pass through the Sun, and move the Hour Circle till the Index points to XII; and as the general Eclipse begins about twenty Minutes after VII, I turn the Globe about till the Index points to the Hour of VII.—And since the Middle of the Eclipse happens a few Minutes after X, I move the Shadow on the sliding Piece towards the left Hand, or western Side of the Globe, by a little more than the Space of half the Duration of the Eclipse, which is shewn by the Hours and Minutes placed on the Slider, each Way from the Middle.—Then having raised the Shadow, by the Scale of the Moon's Latitude placed on the Stem, the Machine is ready for Motion.

Euphros. By all this Preparation, I plainly perceive an Eclipse of the Earth is at hand. When the Machine is in Motion, I cannot help seeing, that the Shadow of that Crape will very naturally represent the Shadow of the Moon, as it passeth over the Surface of the Earth: But how do you adjust that Shadow?—The Sun shines, it is true; but his Beams are so oblique, that I do not see how they are to answer the Purpose, as they at present will fall over the Circle of Illumination, when the Globe is turned towards the Sun, and so the enlightened and dark Hemispheres will not be the same as represented by the Machinery.

Gleon. To all this the Answer is ready and easy;—for the artificial Day and Night may be truly made at any Time by the Sun-Beams, or Candle-light:—For if I place the Globe toward the Sun, and place a Looking-glass on the Table, (between the Sun and the Globe) inclined in a proper Degree, it will throw the Sun-Beams parallel

parallel to the Horizon, and, consequently, every where perpendicular to the Plane of the Circle of Illumination; by which Means, that Part of the Globe will be enlightened, and represent the Day just as it is in Nature.—The same Thing also is to be done by placing a Candle in the Focus of a large Lens, or Speculum, which, by that Means, will be directed parallel to illuminate the Hemisphere required.—But as the Sun-Beams are most natural, and fitted for our Purpose at present, your Dressing-glass will be the most proper to dispose the Rays for making the artificial Day, which you can bring me down and set on this Table.

Euphros. I will instantly go and fetch it;—here it is; and, by the Screws, you will place it in the Position which you know to be necessary.

Cleon. I have duly placed the Table, and put up the Sash, and now the Sun-Beams fall on the Glass.—I move it up and down, till such Time I find the Rays go parallel to the Horizon, and fall on the Globe as they ought.—And now, you have nothing to do but to observe the general Phænomena of the Eclipse, which, upon my putting the Machine in Motion, you will observe to be as follows:

I. You see the Eastern Edge of the Shadow come upon the western Part of the Earth's Surface, and first touch it on the western Parts of *Africa*: Also, that the eastern Part of the Shadow gradually passes along on the Circle of Illumination; and describes a Tract on the Surface of the Earth, shewing all that Part, whose Inhabitants view the Sun beginning to be eclipsed at the Horizon, or that the eastern Limb of the Moon touches the western Limb of the Sun, just rising above the Horizon.

II. Soon after this, you observe the vertical Line on the Crape (which divides the Shadow into the eastern and western Semi-circle) will come upon the Circle of Illumination, and denote that Tract upon the Surface of the Earth where the Sun will appear to rise with the Moon, as far advanced on its Surface as she can be, and where the Eclipse will appear greatest of all at Sun-rising.

III. The Middle of this Line, or central Spot of the Shadow, will come upon the said Circle at its Entrance
on

on the illuminated Disk; and those who inhabit that particular Spot, you will easily observe, must see the Sun rise centrally eclipsed.

IV. As the Shadow advances, you see the western Part coming on upon the Earth's Surface, and in every Part, where the western Edge of the Shadow comes upon the Circle of Illumination, the Inhabitants of that long Tract will observe the Sun Rising, with the western Limb of the Moon just touching the Sun on the lowest, or eastern Part in the Horizon, *i. e.* they will see the Moon go off, or the Eclipse end just as the Sun is risen.—And these will be the Appearances of the Eclipse, at Sun-rising, to the Inhabitants of the western Parts of *Africa* and *Europe* to the North Pole, or a little beyond it, including a large Space on the Surface of the Earth.

V. As the Shadow advances, the greatest Part is received on the Surface of the Earth; but all the upper Part falls off into the Expanse over the northern Regions: And as it rises higher and higher above the Plain of the Ecliptic, so the Center of the Shadow goes northerly till it has described a Tract, obliquely, from the West of *Africa* to the northern Parts of *Muscovy*, where it goes off from the Earth.

VI. By the black Circles on the Crape, round the Center, is shewn how much of the Sun's Surface will be eclipsed from the View of the Inhabitants who live on those Parts, where the Circles pass. Thus they who live in the Tract of the Center will see no Part of the Sun's Disk, but the Sun will be centrally eclipsed to them.—Those who live under the Shadow of the first Circle from the Center, will view ten Digits eclipsed, or ten Parts out of twelve of the Sun's Diameter.—Those who live under the Shadow of the second Circle from the Center, will view but eight Digits eclipsed.—Those who live under the Shadow of the third Circle, see but six Digits, or half the Sun's Diameter eclipsed; and so in Proportion to the other Circles.

VII. Because the Sun's Diameter does a little exceed the Moon's, therefore the Eclipse, where central, will not be total; but there will be a Ring of Light all round on the Edge of the Sun, which occasions such an Eclipse to be called *Annular*. In some Cases, the apparent Surface

face of the new Moon is larger than that of the Sun, and then the Eclipse is central, and total.

VIII. You will next observe, there is a certain Point in the Meridian of the enlightened Disk, a little beyond the Pole, which, while the Globe is turning upon its Axis, does only just touch the Circle of Illumination, but goes not beyond it; in that very Part they view the Sun, in the South Point of the Horizon, neither setting nor rising, with the southern Limb of the Moon just touching it on the northern Edge; and this is the Term where the Beginning of the Eclipse ceases at Sun-rising, and begins at Sun-set: For,

IX. When the eastern Edge of the Shadow has passed this Point, it will come upon those Parts of the Surface of the Earth on the eastern Side, which are passing under the Circle of Illumination, into the dark Hemisphere; and in all those Places which are traced out by the East Edge of the Shadow, applying to the said Circle, the Inhabitants will view the Eclipse begin just as the Sun sets, or they will view the eastern Limb of the Moon, and West Limb of the Sun touching in the Horizon.

X. The vertical Line of the Shadow, as it successively applies to the several Parts of the Circle of Illumination, will trace out all that Part on the eastern Side of the Globe, to whose Inhabitants the Sun will appear eclipsed, in the greatest Quantity that can be to them, at Setting; and in that particular Part where the Middle of the Line, or Center of the Shadow, touches the Circle, the Sun will appear centrally eclipsed at his Setting.

XI. As the Shadow passes on, the western Edge comes, by Degrees, on the eastern Part of the Circle of Illumination, and the Inhabitants of all those Parts which are on the Edge of the Shadow, under the Circle, see the Eclipse end, or the Moon passing off the upper Limb of the setting Sun.

XII. During the Passage of the Shadow over the Earth's Surface, you will observe the Earth keeps regularly moving on upon its Axis, the same Way with the Moon's Shadow, from West to East, by which Means it happens, that a much less Quantity of the Surface of the Earth is obscured by the Shadow, than would have been, had there been no diurnal Motion.

XIII.

XIII. With regard to any one particular Place, as *London*, for Instance, you will observe, that when the eastern Edge of the Shadow comes upon it, the Eclipse begins; and when the western Edge of the Shadow touches it, the Eclipse ends: And when the vertical Line of the Shadow is upon it, the Eclipse is the greatest of all, and the Circle nearest to it will shew the Digits eclipsed.

XIV. The Time of any particular Phase is observed for any given Place, by the Hour Circle: Thus the Beginning of the Eclipse at *London* is there shewn to be a few Minutes after IX, the Middle about twenty Minutes after X, and End at about three Quarters after XI, and that there will be nearly eleven Digits eclipsed.—Such, my *Euphrosyne*, are the Appearances of a Solar Eclipse, the general Rationale of all which, as exhibited in this Manner, I make no Doubt, will be sufficiently evident to you.

Euphros. I think, every Particular you have mentioned, we may, with proper Attention, deduce from bare Inspection:—But your Lesson has been so long, and consists of such a Number of Particulars, that I must take an Opportunity of recollecting, reconsidering, and practising them, at my Leisure; for though it gives me the highest Satisfaction, to have but a general View, or Notion of Things of so sublime and intricate a Nature, yet it cannot be expected that I, or any one, should at once become acquainted with the Nature and Doctrine of Eclipses. I think myself extremely happy, that I have it in my Power to repeat these Phænomena whenever I please, by the Instruments you have been so kind as to provide for my Improvement in this Sort of Knowledge.

Cleon. My Endeavours shall never be wanting to give you the best Idea of Things in my Power, and, ere long, I may put something more into your Hands, that will contribute to facilitate your Knowledge of these Things; but it will be previously necessary, that you should have some distinct Notion of what we mean by the Doctrine of those *Projections* of the Surface of the Globe which we call MAPS and CHARTS: And this will be the Subject of our next Conversation.

DIALOGUE XIV.

On the Nature and Use of Geographical PROJECTIONS, usually called MAPS and CHARTS; with a Specimen of one of a New Construction, comprehending the Western, or Atlantic Ocean, and his Britannic Majesty's Dominions on the Continents of EUROPE and AMERICA.

Cleonicus.

YOU may think it, perhaps, superfluous, my *Euphrosyne*, after we have dwelt so long on the Use of the Globes, to trouble you with any Thing more of a Geographical Nature; but, as I have hinted to you in a former Conversation, the Globes themselves will not suffice for all Geographical Purposes. On the other hand, we are obliged more frequently to have Recourse to what we call Geographical Projections of the several Parts of the Surfaces, on a Plain, which go by the common Names of MAPS and Sea CHARTS; the former of which contain a Part of the Earth's Surface only, the other of the Sea Coasts and Oceans.

Euphros. You need not be afraid of my being tired with such useful and pleasant Studies, as the Science of Geography affords; especially, as I apprehend the Use of Maps is so very considerable, that the greatest Part of our Pleasure in reading Books that give us an Account of the several Parts of the World, is derived from thence; for without them, such Treatises must be very dry and unentertaining: Therefore, let me know as much of their Nature and Use as you possibly can.

Cleon. I will relate to you every Particular that I think can be of Service concerning them; and, in the first Place, we may observe, that they are of two Sorts, General and Particular; a general Map is a Projection of the globular Surface of the Earth, on two circular Planes, which are usually called MAPS of the WORLD. The particular Sorts, are only Maps of some particular Coun-

Countries, Sea Coasts, Seas, &c. How these are made, I shall shew in their Order, and observe to you, the Deficiencies and Excellencies of each, and then present you with a new and general Map, of a Kind that has never yet been published.

Euphros. These are Particulars I should be very glad to be instructed in; and, in the first Place, please to let me know how the general Maps of the World are formed.

Cleon. I will; but, for this Purpose, you must call to your Assistance the Power of Imagination, and suppose, that you had a Hemisphere, or Half Globe of Glass, and that the Base of this Hemisphere was every where terminated by the general Meridian that passes through the Island of *Ferro* in the western Ocean.—Then you must imagine, that over all the Surface of this glass Hemisphere, the various Continents, Kingdoms, Countries, Oceans, Seas, &c. are all nicely drawn, in Water-Colours, so as to represent completely the eastern Hemisphere of the Globe, divided by such a Meridian.—Then, in the next Place, suppose a Glass Plane were placed upon the Base of this Hemisphere, and then both placed in a perpendicular Situation to the Eye, you can easily conceive that all the Parts of the painted Hemisphere will appear upon the Glass Plane, as if they were there projected by the Rays of Light drawn from every Part of the painted Hemisphere to the Eye.

Euphros. All this I can easily image to my Mind: I could wish nothing was more difficult than the Power or Art of Imagination.—But whereabouts, and at what Distance must the Eye be placed to view them as they appear in Maps? For I readily understand, that this Glass Plane, with the Geographical Delineations upon it, is the Map you are speaking of.

Cleon. That is the very Thing.—The Eye, at a certain Distance, views the transparent Hemisphere, and projects its variegated Surface on the Plane:—But, according to the different Distance of the Eye, different Sorts of Projections will arise, and consequently different Maps of the Hemisphere will thereby be formed.

Euphros. Well, but since the common Map of the World is in all our Houses, my Curiosity induces me, first,

first, to inquire, where the Eye is to be placed for viewing the Hemisphere so as to produce such a Map on the glass Plane?—

Cleon. The Situation of the Eye in that Case, my *Euphrosyne*, is exactly against the Middle of the Hemisphere, and that the Distance is half of the Diameter of the said Hemisphere, or Globe: Thus, for Example, suppose the Globe were twelve Inches in Diameter, then the Point of Sight, or Place of the Eye, is just six Inches from the Center of the Hemisphere.—The Eye, in that Position, or at that Distance, views, upon the transparent Plane, the Surface of the eastern Geographical Hemisphere exactly the same as you see in a twelve Inch Map of the World, in the right-hand Circle.

Euphros. I very clearly understand your Meaning; and in the same Manner, the Map in the left-hand Circle, including *America*, is also formed; you need say no more to me on this Head, as I am fully satisfied of the Manner of making these Maps: But their peculiar Properties, or Character, I should be glad to hear you rehearse.

Cleon. These I will enumerate in Order; and first, it must be observed, that the globular Surface of the Earth cannot by any Means be so represented on a Plane, as to preserve that Proportion and Relation of all the Parts to each other, as they have on the Globe itself; but in this common Map, or Projection, we are now speaking of, that Proportion and Relation is less preserved, or the Countries more distorted, than in any other Sort of Maps in common Use, even to such Degree, that you observe* the Meridians and Parallels are almost twice as near together in the Middle Parts of the Map, as they are on the Outside: Whereas on the Globe, they are every where at an equal Distance; which Equality of Distance ought, as much as possible, to be observed in Maps: Since, when those Distances are so very unequal, the Magnitudes of the several Parts of the Country will vary greatly from the Truth, or from the Proportion which they have among themselves. Thus, for Instance, the Isle of *Madagascar*,

* The Reader is here supposed to have his Eye upon one of those common Maps of the World, as that in the Beginning of *Salmon's Geographical Grammar, &c.*

in the Middle of such a Map, appears near four Times less than it would do if placed on the Outside ; and the Island of *Great Britain*, near the Meridian, appears, in Proportion, as much larger than what it would do placed in the Middle of the Map.—Not only, therefore, the particular Dimensions, but also the Bearings, Distances, and other Geographical Relations of Places, are hereby very much perverted, which, as they give wrong Ideas of Geography, and lead the Mind to Error, must certainly prove this Sort of Map of very ill Consequence to the literary Republic, and fit only for the Amusement of ignorant Persons.

Euphras. If those Maps justly deserve so bad a Character, as you have plainly proved, I would be glad to know how they came into such general Use ?

Cleon. It is in this as in all other Cases ; bad Things generally have their Rise in Ignorance, and are continued by Custom.

*Custom, that Mankind into Slavery brings ;
The dull Excuse for doing silly Things.*

ROSCOMMON.

And there can be no other Apology for such a vicious Sort of Maps, which are the standing *Opprobrium* of the learned World ;—but of these we have said enough, and more than they deserve.

Euphras. What Sort of Projection, or Map, would you then recommend as approaching nearest to the Properties of a Geographical Map on the Globe ?

Cleon. To this I will give you an Answer in few Words :—There are certain Positions of the Eye, in which the Meridians will be projected, on the transparent Plane, at equal Distances from each other ; but there is no *one* Position of the Eye in which they appear so. However, it was always easy, by the Rules of Art, to draw them in this Manner, as well as all the Parallels, equally distant in the middle Parts of the Map ; and since, in this Case, the Inclination of Meridians is every where the same as on the Globe, and the Distance of the Parallels in all the middle Parts the same as on the Globe, therefore this Projection has deservedly merited the Title it bears, *viz.* the *Globular Projection*, or Map of the World

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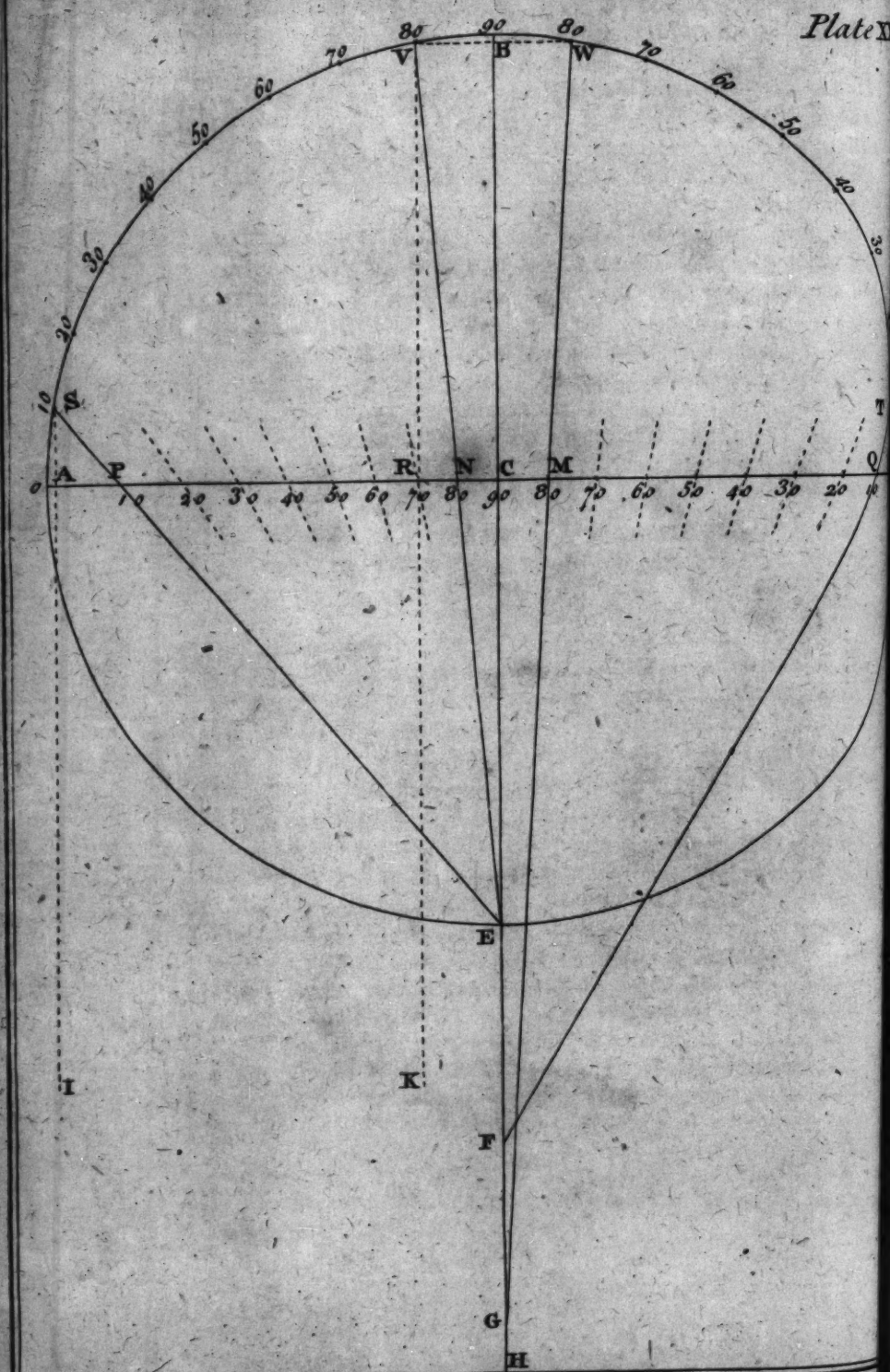
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Plate XV



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World—of which this is a particular Specimen *, which I present to you for your Use.

Euphros. I am greatly obliged to you for this curious Present, and for the Care you take that my Ideas are formed on the justest Plan.—I can, indeed, so readily perceive a Difference between these and the common Maps, that I cannot but wonder how one of so much Beauty, Elegance, and Truth, should have been so little regarded, in Comparison to that vulgar, erroneous, and deformed one in common Use.—I can easily perceive, that in this new Map of the World, the Countries have the same Proportion, nearly, as they have on the Surface of the Globe, so much, indeed, that when I compare them with the Globe itself, I can scarcely perceive the Difference.—Pray, what other Maps of the World are there, besides those you have already mentioned?

Cleon. There are none of general Use; some have been made, by projecting the Surface of the Earth on the Plane of the Horizon, which have their particular Uses.—Others are made on a particular Scale, called *Mercator's Projection*; in which the Meridians are all strait Lines, and parallel to each other; and in which the Degrees of Latitude increase in Proportion as the Degrees of Longitude decrease, in going towards the Poles; but these are chiefly in Use in Navigation, though not altogether unworthy the Notice of any young Lady, or Gentleman, inclined to Philosophical Studies. I need not insist any longer on the Nature of general Maps, or their Uses in finding the Latitude, Longitude, &c. of particular Places, since these are common Topics you are, by this Time, full well acquainted with †.

* See the NEW GLOBULAR PROJECTION, or Map of the World, with a Solution of all Geographical Problems, in a circular Space about each Hemisphere: Also, the Map of the World at the Beginning of the *Philosophical Geography*, Page 33.

† Such of our Readers who desire a more particular Illustration of this Affair, may please to cast their Eye upon a *Diagram* in Plate 39, where A B D is the Hemisphere above described, and A C D the transparent Plane on its Base; the Point E is the Place of the Eye, to view the several Parts of that Hemisphere upon the Plane, according to the common

Euphros. You intimated, there were different Sorts of particular Maps: I should be glad to know their Difference and Peculiarities.

Projection, that is, EC is equal to AC . The middle Point of the Hemisphere at 90° will be projected on the Point C in the Glass Plane; and if from the Point V the Line VE be drawn, it will represent the Ray of Light projecting the 80° in the Point N ; and if from the Point S we draw the Line SE , it will be that Ray of Light which projects the 10° upon the Point P in the said Plane. Now from a Table of natural Tangents it may be shewn, that AP , the Projection of 10° on the Side of the Plane, is almost twice as large as NC , the projected Distance of 10° in the Middle of the Plane; and if Lines were drawn from E to $20, 30, 40, 50, 60$, and 70° in the Hemisphere, they would intersect the Plane in the dotted Lines which you see placed there by the same Numbers, and the Intervals between those Lines on the Plane will be all unequal: But these are the several Points through which the Meridians are drawn, which shews the Reason why all the Meridians are at unequal Distances in the Equator of our common Maps.

But if you now cast your Eye on the other Side of the Hemisphere, you will there perceive the Line CD divided into 9 equal Parts, and the 80° at W will be projected on the Point M in the Plane, by a Ray drawn from W to the Point M , and meeting with the Axis of the Hemisphere (continued out) in the Point G , which, therefore, will be the Place of the Eye in this Case. Then, on the Hemisphere, from 10° at T draw a Line through the Division at Q , this will meet with the Axis of the Hemisphere in the Point F , where the Eye must be placed from the Projection of the first 10° ; and since all the Intervals are equal between Q and M , the dotted Lines passing through their Divisions, there marked and directed to the correspondent Numbers in the Quadrant DB , will all be directed to Points between F and G ; and therefore, in Case of the globular Projection, the Eye has not one Position, but must be conceived to move through the Space FG , to view the several Parts which lie between D and B , in the same Proportion and Distance on the Plane CD , as they have in the Hemisphere itself between D and B . If the Radius of the Globe CE be supposed to consist of 100 equal Parts, then CF will be 160, and CG will be 175. If the Eye be supposed removed to an infinite Distance, then will all the Rays which proceed from the several Divisions

Cleon. These, with respect to particular Places, are a much juster Representation of them than general Maps can be; for, if only one Kingdom or Country is to be represented, this may be done, nearly, with as much Truth as on the Globe itself, and is of much greater Advantage in one Respect than even the Globe, as it will admit of a much larger Scale, and, of Course, a more spacious, distinct, and exact Delineation of any such particular Country.

Euphros. This I immediately see the Reason of, since a small Tract, or Area, on the Surface of a Globe, differs very insensibly from a Plane.—Thus, the circular Space of ten Degrees on the Surface of a twelve Inch Globe, differs but very little from the Plane, and yet comprehends the Island of *Great Britain*, and all the adjacent Country and Coast about it.—On larger Globes, it must differ still less from a Plane; and therefore the Parts of *Great Britain*, the *English* and *Irish* Channel, *German Ocean*, &c. when laid down from a large Scale, must be considered as Part of the Surface of a very large Globe.

Cleon. What you observe is very just, and you may easily know how large the Globe must be, to have the Country of the same Dimensions upon it as you see in the Map.—Thus, for Instance, if you see a Map in which the Degrees of Latitude on the Side thereof are just one Inch in Length, then a Globe, of which that Map is a Part of its Surface, will be ten Feet in Diameter; for there will be 360 Inches in its Circumference; because each Degree is one Inch in Length, and the Diameter of such a Globe being a third Part of its Circumference,

10, 20, 30, &c. as *S I*, *V K*, will be parallel among themselves; and therefore the Projection of 10° in the Middle of the Hemisphere, by the Ray *V K*, will be *R C* equal to *V B*, the Sine of 10° : But on the Side of the Hemisphere the Projection of 10° , by the Line *S I*, is no more than *o A*, which is the versed Sine of 10° , and is very small in Comparison of *R C* in the Middle. In this Projection, the Meridians are Ellipses, and constitute the *Analemma*, or Orthographical Projection of the Sphere, of considerable Use in Astronomy, and will be hereafter more fully explained.

nearly, or 120 Inches, which is just 10 Feet:—Therefore a Map, where the Degrees of Latitude are half an Inch in Length, will be the Part of the Surface of a Globe half so much in Diameter, or five Feet:—If the Degrees in a Map are $\frac{1}{2}$ Inch each, the Diameter of the Globe will be thirty Inches.—On the other hand, if the Degrees of Latitude are two Inches long on any Map, then such a Map is Part of the Surface of a Globe twenty Feet in Diameter, and so in Proportion for Degrees of any other Length.

Euphros. By this, I am at once convinced of the great Utility of particular Maps of Countries, since they present us with a just View of the several particular Parts of the World, as they would appear to the Eye on the Surface of such very large Globes, which it is not in our Power to have.——

Cleon. But besides what you have now very pertinently observed, there is one considerable Advantage accruing from such particular Maps which we could by no other Means become possessed of:—I mean, that in such Maps we can easily express the true Form and Dimensions of Countries, together with the Lengths of the several Degrees of Latitude in the same Proportion as they lie on the Surface of the Earth itself, that is, on the Surface of a *Spheroid*, and not of a Sphere or Globe: For, as any Globe we are capable of making will be much too small to shew that Difference which would be very sensible in Globes of 20, 30, or 40 Feet in Diameter, we still enjoy that Advantage in Representations of the particular Parts of such very large Globes, in our common Geographical Maps of Countries.

Euphros. If I understand you right, our Maps of Countries should be taken from the Surface of a Spheroid, and not a Sphere; and that the Degrees of Latitude in them should not be precisely equal, as we find them in common Maps.

Cleon. That is the Case. Our Maps are supposed to be the Representations of Spheres, when they might, at the same Time, be as well made to represent a Spheroid of the same Dimensions, wherein not only the Degrees are of an unequal Length, but likewise the Extent, Situation,

tion, and Form of Countries are very different, on a Spheroid, to what they are on a Globe.—Thus, for Instance, the Situation of *England*, on the Surface of a Spheroid 10 Feet, is almost a whole Inch nearer to the Equator, than it is on a Globe of the same Diameter;—Also, a Map of 10 Degrees Extent, in the middle Parts of the temperate Zone, will be larger than one of 10 Degrees Latitude near the Equator, and less than another of 10 Degrees within the polar Circle; whereas, our common Maps of 10 Degrees Extent, for any Part of the Globe, are always equal.

Euphros. Such a material Point as this one would think would greatly excite the Curiosity of all the Critics in Geography; and I wonder it has as yet been so very little attended to.

Cleon. It would be a Wonder with every one, as well as with yourself, were it not considered how great the Difficulty is to conquer any Thing established by common and universal Practice.—Our Logic extends to little more than this: *They have ever been made so, and therefore they ever must.* And our very Critics themselves have so much Candour and Ingenuity as to treat every Thing with a supercilious Sneer, and to represent as a Novelty, of no Importance or Use, whatever they have not the Fortune to hit upon themselves: However, we shall always find Numbers who are candid and judicious enough to encourage any Invention which tends to the Perfection of any Art or Science, though there were nothing else to recommend them: It has been largely shewn, that the Discovery of the true Figure of the Earth is of this Kind, and that Geography, Navigation, Astronomy, and many other Sciences, receive very great Improvements in many Particulars from it: And therefore such a noble and important Discovery ought not to be omitted, or neglected in our Maps; for which Reason, a NEW SYSTEM OF GEOGRAPHY, for the Use of our *British* Youth, whose Maps are all formed upon a Plan of the new Discovery abovementioned, becomes absolutely necessary, if we regard either the Truth or Honour of this delightful Science of Geography.

Euphros. Such a Set of Maps I should greatly rejoice

to see *, as I have no Notion of being satisfied or contented with a bad Thing, when better may as well be had; for I apprehend there is no more Expence or Difficulty attending the one, than the other.

Cleon. There is not in the least: and you will shortly be gratified in this Respect.—There is yet one other Species of particular Maps, which is quite of a *new Invention*; and as it is a great Curiosity of this Kind, and no Map has been hitherto constructed on the Plan, I have been at the Trouble of drawing one myself, on Purpose to make you a Present of it, as I wish to have nothing new or curious go beside you, or come to you at Second-hand.

Euphros. Pray, let me look at it.—It seems to be an elegant Design; and differs manifestly from the Appearance of other Maps; but in such Particulars, as I can hardly tell what they are.—I see it is very capacious, and takes in large Tracts of the Continent of *Europe*, *Asia*, and *Africa*, on one Side, and of *North America* and the *West-Indies* on the other Side, with a View of all the *Atlantic Ocean* between them; and yet, methinks, the Map is not large, for such an extensive View.

Cleon. There is somewhat very singular in the Construction, as well as the Form of this Map.—Would you ever have thought of a Representation of the Surface of the Globe, by a Part of the Surface of a Cone? And yet you will easily understand that this is the Case in regard to the Map under Consideration; for you may plainly see, that the Form of the Map itself bespeaks it to be a Part of the Surface of a Cone;—and the Surface of a Cone, you know, may be easily formed of any plain Piece of Paper, cut into a circular Form or Base; and you will as easily consider, that if a Cone, about twice the Height of the Semi-diameter of the Globe, were to

* The *New SYSTEM of GEOGRAPHY*, for the Use of Schools, is that which is now published under the Title of *PHILOSOPHICAL GEOGRAPHY*. In which all the Maps are strictly the Representations of so many Parts of the *spheroidical Figure* of the Earth, and the Degrees of Latitude divided into Minutes; also the Difference between those Degrees, as they lie on the *Spheroid* and *Sphere*, is specified in every Map.

be conceived as standing on the same Bases with the Hemisphere, that is, on the Equator, the Surface of such a Cone would in Part lie within the Surface of the Globe; and then, nothing can be easier than to suppose that the Surface of the Globe, at so small a Distance from the Surface of the Cone, might be very easily projected and delineated upon it; and in such a Case, the Proportion of the Countries, and their Bearings, Distances, &c. will be nearly the same on the Surface of the included Part of the Cone, as on that of the Globe itself; and when such a geographical conic Surface is cut out, and expanded, it makes the Map which you have in your Hands.—The principal Peculiarities of this Map are as follows.

I. All the Meridians are right Lines, but converge towards the Vertex of the Cone, as the circular Meridians on the Globe converge towards the Pole.

II. The Distances, North and South, are exact; and any Meridian will serve as a Scale, to measure these Distances by, in this Respect; so far as the Map extends, it is, indeed, as true as the Globe, on which the Degrees of Latitude are all equal; but neither this, or any other Map, or Chart, can have the Distances, North and South, so true as those which are made from a Projection of the Spheroid, as I have before observed to you.

III. The Parallels of Latitude, in this Map, are all Equi-distant, or truly parallel to each other, as they are on the Globe.

IV. The Meridians and Parallels intersect each other at right Angles, as on the Surface of the Globe.

V. As such a Cone, on which this Map is made, is supposed to pass through the Surface of the Globe in two Places, the Parallels of Latitude, in those Places where the Cone intersects the Globe, will be the same in the Map as on the Globe itself, *i. e.* all Distances East and West may as truly be measured upon them; which Parallels, in the Map before you, are those of 20 and 50° Latitude.

VI. But since the Middle Part of the Map on the Surface of the Cone lies within the Globe, the Meridians on that Part of the Globe will be at a greater Distance than those Parts of the Meridians projected on the Map, and,

and, consequently, the Parallel of 35° , and those near it, will be deficient from the Globe, or give a less Distance than what is just; or any two Places on the Middle of such a Map must be represented something nearer together than they are upon the Globe, if their Longitudes be exactly expressed.

VII. On the other hand, those Parallels which terminate the Map have an Error in Excess: Thus the Parallel of 10 and 60° , as they are projected from Parts of the Globe which lie within the Cone, must have a greater Space between the Meridians than their corresponding Parallels on the Globe have: And thus, Places in those Parts of the Map are represented at too great a Distance from each other.

VIII. The quadrangular Spaces formed by the Meridians and Parallels, have their Diagonals equal to each other, as on the Globe itself; which is a Property peculiar to this Projection, which is not a rectilineal one.

IX. The Quantity of Surface represented on this Map is exactly the same as that of the same Extent on the Globe itself, and therefore differs no more from the Truth of the spheroidal Projection, than a Globe does from a Spheroid, which is the true Figure of the Earth *.

X. As the Errors in one Part of the Map are in Excess, and the other in Defect, and the Extent of each nearly equal, they will, upon the Whole, in a great Measure compensate each other, and are in general of the least Quantity they can have in the Map designed.

XI. As a Thread extended from any one Place to another, on the Map, will, when the Map is restored to its conic Surface, still pass through the same Points, therefore the shortest Distance between any two Points on this Map is the right Line that joins them; and therefore such Distances applied, by the Compasses, to a graduated

* As some of our young Mathematical Readers may be desirous of seeing a Demonstration of the Nature and Construction of this Map, and the several Properties here enumerated, deduced therefrom, we have thought proper here to add it by Way of Note, and to illustrate the same with a proper Diagram.

duated Meridian, will very nearly shew the true Distances of the Place represented in Degrees, Miles, or Leagues, as is done by the Quadrant of Altitude on the Surface of the Globe itself.

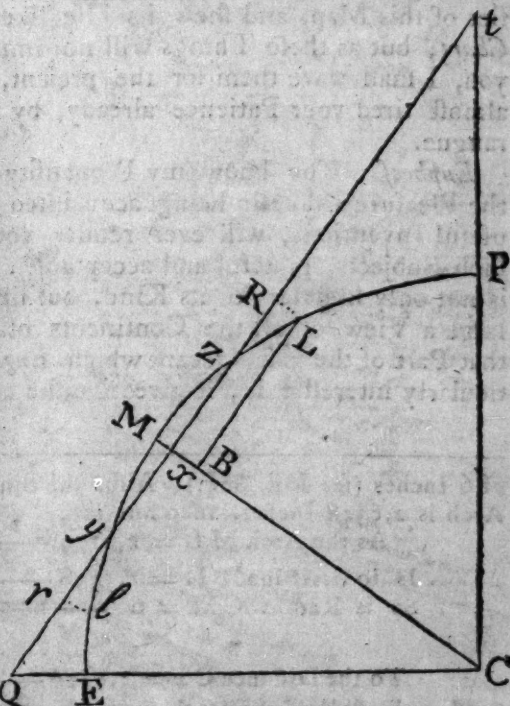
XII.

The learned Author of this Invention has given us the Theory thereof from *Archimedes*, but as we can easily derive it from our own Institutes, we apprehend that will be most agreeable to our Readers. Let *EMP* be the Quadrant of a Meridian of a Globe twelve Inches Diameter; whose Center is *C*, and Pole *P*. *EL*, *EP*, the Latitudes of two Places in that Meridian; *EM* their middle Latitude. Draw *CM* and therein find the Center of Gravity (*x*) of the Arch *LI*, (by 1077) and thro' *x* draw *Qt* perpendicular to *CM*, it will intersect the Arch *LI* in the Points *y* and *z* equidistant on each Side from the Point *M*. Lastly, in the Line *Qt*, make *xR*, and *xr*, equal to the Arches *ML* and *MI*, respectively; then the conical Surface generated by the right Line *Rr*, while the Figure revolves about the Axis *Ct*, will be equal to the Surface of the Zone of the Globe that is described at the same Time by the Arch *LMI*, (by Inst. 1085.)

For Example, by the Problem (Inst. 1077) we have $Cx = \frac{CM \times LB}{ML}$, which gives this Analogy; as any Arch *ML* is

to its Sine *LB*, so is Radius *CM* to *Cx*, the Distance of the Center of Gravity *x* of twice that Arch, *LI*.

In this new Map, the Extent or Difference of Latitude is $50^\circ = LI$; therefore $ML = 25^\circ = 2,6179$ Inches to a Radius of



XII. In Maps of this Kind, which are but of small Extent in Latitude, as 10, 15, or 20°, the Errors in Geography will be extremely small, and may be looked upon as sufficiently exact for any common geographical Purposes.

I might enlarge farther on the Novelty and Peculiarities of this Map, and shew its Use likewise as a *nautical Chart*; but as these Things will not immediately concern you, I shall wave them for the present, as I fear I have almost tired your Patience already, by so tedious an Harangue.

Euphras. You know my Propensity to Science, and the Pleasure I take in being acquainted with all new and useful Inventions, will ever render your Discourses, on such Subjects, grateful and acceptable: And as this Map is not only singular in its Kind, but likewise contains so large a View of all the Continents of the World, and that Part of the vast Ocean which *England* is more particularly interested in, it gives me the highest Pleasure to peruse

of 6 Inches (see Inst. 885.) Also, the Sine B L of the same Arch is 2,5358 Inches, therefore say,

As the Arch M L = 2,6179 ——— 0,417953

Is to its Sine B L = 2,5358 ——— 0,404099

So is Radius C M = 6 ——— 0,778151

1,182250

To the Distance C x = 5,8116 ——— 0,764097

So that the Side of the Cone Q x falls within the Zone L M about $\frac{1}{5}$ of an Inch = M x, which is the versed Sine of 14°: 24' = M z or M y.

From this Construction it is evident, that in a Map made on the conic Surface between R and r, the Distance of the Meridians in the middle Part at x will be less than on the Globe at M; and on the extreme Parts at R and r, they will be wider asunder than on the Zone of the Globe at L and I; and lastly, at z and y they will be equidistant on the Cone and Globe.

It is farther evident, that as the Point M advances to the Equator E, the Point I will arrive at and pass the Equator into southern Latitude; till at last the Point M coincides with E, the Cone becomes a Cylinder, and the Map takes in equal Degrees of both Latitudes, but its Properties otherwise continue the same. Upon the Whole it appears, that a Map in no Kind of Projection can be so true and perfect as on the Globe itself.

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A New GEOGRAPHICAL MAP
of the
ATLANTIC OCEAN with the **COASTS**
OF EUROPE AFRICA & AMERICA
on the East & West Side of it.



This
CHART is
that Projection of the
Spherical ZONE on the
Surface of a CONE Invented by the
R^D M. MURDOCH & described in *Phil: Trans:*
Vol: L. 1758.

Engraved for the General Magazine, of Arts & Sciences, for W.

AL MAP or CHART

with the Continents of
AMERICA &c:
Side of it.

W. from 20 London 10



ences for W. Owen at Temple Bar 1763.

peruse it. — I here see our Situation with respect to neighbouring Nations, and other Parts of the World. — I view his *Britannic Majesty's* Dominions in all Parts of *Europe* and *America*: I survey the Coasts, Roads, and Tracts which our Fleets pursue in their destined Departments in the remotest Parts of the World — The Ocean is chequered with Islands, the *Azores*, *Madeira*, *Cape Verd*, *Canary*, the *Bermudas*, the *Caribbee* and *Bahama* Islands; with the *African* and *American* Coasts. — In short, I shall always look on this Map as one of the greatest Curiosities in my Possession, especially as it is an Improvement in that Science which of all others, though the most useful, has been the most neglected by Men of Genius and Learning, as you have more than once informed me.

DIALOGUE XV.

The various Phænomena of the TRANSIT OF VENUS over the SUN, June 6, 1761; together with the Uses thereof, in discovering the PARALLAX and Distance of the SUN and PLANETS: Exhibited and illustrated by the TERRESTRIAL GLOBE, and an astronomical Diagram.

Cleonicus.

THE Drift of my Endeavours, in all our past Conversations, has been to embue your Mind with the Principles of Astronomy and Geography, so far as they could be supposed useful and becoming to one of your Sex; and my Experience has satisfied me, that those Topics have afforded you an agreeable Amusement and Pleasure.

Euphros. Indeed, *Cleonicus*, they have; and I shall always reckon the Hours, so spent, make the happiest and most pleasurable Part of my Life: — I begin to suspect, by what you say, that you are coming to a Conclusion of those most entertaining Studies.

Cleon. When they are finished, others will offer equally agreeable; but there is, my *Euphrosyne*, one *Phænomenon* yet

yet to come, that is both of an astronomical and geographical Nature:—A Phænomenon by far the noblest that all Nature affords, and on which the greatest Things depend:—It is what I was the other Day mentioning to some Gentlemen when you was in Company, and I observed you paid a more than ordinary Attention to it at that Time.

Euphros. You need say no more, *Cleonicus*; I recollect, and shall never forget what you told us at that Time, of the Transit of *Venus* over the Sun's Disk.—I can assure you, it has been in my Thoughts almost ever since; and there is scarce any Thing at which I more rejoice, than the Thoughts of its being so near at Hand, though, from some Part of your Discourse to those Gentlemen, I am afraid of two Things: The first is, whether we may be permitted to enjoy so curious a Sight, on Account of the Weather; and, secondly, whether I may be capable of understanding so much of the Nature of it, as to be apprized of its great Usefulness and Advantage to Mankind, on which you then so largely descanted.

Cleon. The first of your Fears it is not in my Power to remove, we must hope for the best; I am as full of Apprehensions on that Account as you yourself can be: No Event to Astronomers will be so malignant and disastrous as a cloudy Day on the 6th of *June*, 1761;—*Avert it, Heavens!* ought to be the Prayer of all that wish well to the Sciences.—But as to the other Affair, your Capacity of understanding the Circumstances of this Phænomenon (excepting the Mathematical Part only) is out of Dispute, especially when you are assisted by the Use of the terrestrial Globe, and a proper Diagram representing the Motion and Parallaxes of those Luminaries.

Euphros. You are always ready to encourage me in the Pursuit of these Studies; but in regard to this Particular Phænomenon, I observe, you make Use of some Words of which I have not the least Idea; the Parallaxes of *Venus* and the *Sun*, which so frequently occurred in your Discourse, are what I know nothing of.—You told them, that the Parallax of *Venus* would be discovered by Means of that Transit;—that by the Parallax of *Venus*, the Parallax of the *Sun* would be discovered;—that the Parallax of the *Sun* being known, the Distance of the *Earth*
and

and all other Planets from the *Sun*, and from each other, would become known also.—These are great Things, it is true; but as they all result from Parallaxes, it is at present all parallatical Myſtery to me.

Cleon. You ſeem to be much gravelled with the Word Parallax, my *Euphroſyne*; I own, it is *Greek*, and has a harſh Sound: But this is not the only *Greek* Word that has a harſh Sound, and an eaſy Signification; for the Idea it conveys is as ſimple and as eaſy as any Word can poſſibly have:—It means nothing more than the Difference of Place in which any Thing will appear when ſeen from two different Poſitions of the Eye, as will be eaſy to illuſtrate my Example.—I take this Candle and ſet it on a Table againſt the Wainſcot, on the other Side of the Room;—Then, as you ſit on that Side the Fire-place, and I on this, if we both look at the Candle at the ſame Time, we each of us ſee it in a different Place, or on different Parts of the Wainſcot; for the Place here meant is not the real Place of the Candle, but that on which it appears on a Plane, placed on one Side or the other:—and thus you may conceive, if an Eye was placed in the Center of the Earth, and another on the Surface, and both together were to view the Planet *Venus* as ſhe paſſes over the *Sun*, then the Face of the *Sun* is to be conſidered as a Plane placed beyond the Planet, and on which the Planet will appear in two different Parts, as viewed by the Eye in two different Poſitions, viz. the Center and Surface; and this Difference of Place is what we call the *Parallax* of that Planet. But this will be much eaſier to conceive from a Diagram, in which you will, by and by, ſee this whole Affair repreſented.—At preſent, your Buſineſs muſt be to familiariſe this Phænomenon to your Mind, by a Representation thereof, under all its various Circumſtances, by Means of the terrestrial Globe, in which you will find no Sort of Difficulty.

Euphroſ. You will firſt put me in a Method how I muſt go about it; for without ſome previous Inſtruction, notwithſtanding all you have ſaid concerning the Uſe of the Globe, it will ſtill remain uſeleſs to me in this Particular.

Cleon. What you now say proceeds only from your not considering one Thing, viz. that the Subject, or Transit of *Venus*, is on the Face of the *Sun*, and, consequently, that you have little more to do than to practise those Problems over again which require you to find all those Parts of the Earth where the *Sun* is visible in the Meridian, or in the Horizon, as Rising or Setting, on any given Day or Hour.

Euphros. By what you now say, I suppose the first Thing I have to do is to find the *Sun's* Place in the Ecliptic for *June 6, 1761*: But to what Hours of that Day is the Problem limited?

Cleon. The Moments of the Beginning and End of the Transit are the principal Times to be regarded, and all the Time between them, of Course:—These Moments, according to the sagacious *Dr. Halley's* Account, are 24' after two o'Clock in the Morning for the Beginning, and End at 29' after IX in the Forenoon, i. e. *Venus* will be seen a round black Spot in the Face of the *Sun*, touching the east and west Limb thereof at those Moments, just in the Manner you see here represented in this Print, of which more by and by.—But to return to the Globe: As the Transit begins at the Time specified, the first Thing you have to do will be to find all those Places of the Earth where the Beginning of the Transit will be visible.

Euphros. In order to that I observe, for the given Day, the *Sun's* Place is in the 16° of *Gemini*, and its Declination $22^{\circ} 30'$.—Now, as the Globe must be rectified to that Degree of Declination, I must bring the said $22^{\circ} 30'$ on the North Part of the Meridian to the Horizon: Then I bring the City of *London* to the Meridian, and hold it there while I place the hour Index to twenty Minutes after II in the Morning:—This done, I revolve the Globe till the Index points at the Hour of XII, and then I observe that all the Hemisphere above the Horizon will see the *Sun* at that Time, and consequently view the Beginning of the Transit, which therefore will be visible to almost all *Asia* and a great Part of *Europe*; but to the western Part of *North America* only.—By casting my Eye below the Horizon, I see the whole Continent of *Africa*, with great Part of *Asia*, *Europe*, and *America*,

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America, deprived of this glorious Sight, the *Ingress* of *Venus* upon the *solar Disk*, and amongst them is the *Island* of *Great Britain*.

Cleon. So far you have performed very well, my *Euphrosyne*; but with regard to this *Transit*, it is a material Point to know in what *Parts* of the *Earth* the *Ingress* or *Beginning* of the *Transit* is visible at *Sun-rising* and *Sun-setting*.

Euphros. This is seen in the same *Position* of the *Globe*; for all those who are in the western *Horizon* of the *Globe* observe the *Sun* rising, with the *Planet Venus* just entering upon its *Disk*: such are all the *Inhabitants* of the midland *Parts* of *Sweden*, *Muscovy* in *Europe*, *Asia Minor*, and *Arabia*.—And those to whom the *Transit* begins at *Sun-set* are such as lie under the eastern *Edge* of the *Horizon*, such are all the *Parts* of *New Britain*, *New Wales*, and the more western *Parts* of *North America*.

Cleon. Very good, *Sister*—You will particularly observe, that *Hudson's Bay* is among the *Number* of those last mentioned *Places*, and especially *Port Nelson* at the *Mouth* of *York River*, as it has a little *Elevation* above the *Horizon*, and therefore will see the *Beginning* of the *Transit* about $\frac{3}{4}$ of an *Hour* before *Sun-set*: The *Reason* why I observe this, you will see by and by.—You will next let me see all the *Parts* of the *Earth* where the *Middle* of the *Transit* will be visible, which happens at 55' past five in the *Morning* with us.

Euphros. For this I have nothing more to do than only to bring *London* to the *Meridian*, and placing the *hour Index* to the given *Time*; then by revolving the *Globe* till it points to *XII* at *Noon*, I view all the *Parts* of the *Earth* where the middle *Moment* of the *Transit* will be visible, which will be in all *Europe*, *Asia*, the greatest *Part* of *Africa*, but scarcely in any *Part* of *America*, unless *James's Isle* and *Greenland* be reckoned such.—It is farther evident, that all those *Places* that are in the western *Horizon*, viz. the western *Parts* of *Africa*, see the *Sun-rising* with *Venus* half *Way* advanced in her *Path* over his *Disk*:—But in the eastern *Horizon* there is no *Land*, and consequently none to observe this *Part* of the *Phænomenon*. at *Sun-set*, but such as are sailing on the *Ocean* there.

Cleon. All this is so far very well, my *Euphrosyne*; but there is one Thing farther to be observed, while the Globe remains in this Position, and that is, you are to take particular Notice of those Places which lie under the Meridian at the same Time, and consequently see the Middle of the Transit at XII o'Clock, and amongst them, to observe that Place more especially to whom the Sun is then vertical.

Euphros. The Places which lie under the Meridian are all the midland Parts of *Asia* from *Nova Zembla* to the *East Indies*, and those whose Latitude is equal to the Sun's Declination, viz. $22^{\circ} 30'$, must have the Sun vertically over their Heads, which I see is a Place I have heard much talked of, the eastern Parts of the Kingdom of *Bengal*, near the Mouth of the River *Ganges*.

Cleon. This Particular you will bear in Mind for a few Minutes.—You will, in the last Place, shew all those Places of the Earth where the Transit ends at Sun-rising, at XII o'Clock, and at Sun-set.

Euphros. The End of the Transit, if I remember right, you told me was half an Hour after IX, — therefore I bring *London* to the Meridian, and place the Index to the given Time, then turning the Globe about till the Index points to XII, and casting my Eye on the western Horizon, I observe, that a few Inhabitants of *North America* and the eastern Part of the *Brazils* in *South America* will view the Sun rising, with the Planet just making its Exit from its Disk — In the eastern Parts of the Horizon there is very little Land except *New Guinea*, *New Holland*, and the Islands called the *Ladrones* on the East of *Asia*, to view the End of the Transit at Sun-set. And those Persons who lie under the Meridian, as all the midland Parts of *Muscovy* in *Asia*, of *Syria*, the *Red Sea*, and eastern Coast of *Africa*, view the End of the Transit at Noon: And amongst them, those at *Jodda*, on the eastern Coast of the *Red Sea*, have the Sun then vertical to them.

Cleon. Indeed, my *Euphrosyne*, you have excellently well executed what relates to the Geographical Part of this Transit, as far as we have hitherto considered it. It remains now, that we make the proper Use of it in discovering the different Times of the Continuance, or Duration

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ration of the Transit, as it may be observed from different Parts of the Earth's Surface.—But in order to this, it will be necessary you should be advertised of one Thing, and that is, that when we behold any Body in Motion, the Celerity, or Quickness of the Motion will be different, according to the Circumstances of our own Situation, in regard to Rest or Motion: For, (1.) If we ourselves are at Rest, we see the Body move with its true, or real Celerity of Motion. (2.) But if we ourselves move, and the same Way with the Objects, its Motion, or Celerity will appear to us to be less, or slower than it really is. (3.) If we move the contrary Way to the Object, it will appear to move much quicker, or with a greater Celerity of Motion than it really has.

Euphros. This last Observation I remember to have often seen verified in a Stage-Coach; for as I have been going to, or coming from Town, the Coaches which we have met on the Road have always appeared to pass by us with a Motion much swifter than we were well assured they really had. — As to the first Observation, it is evident to common Sense; — but the second requires some Attention, though not a great deal, when I consider that oftentimes going upon the *Thames* in a Boat, I have observed the Boats that we meet always appear, like the Coaches, to pass by us with a Motion much greater than our own; but those which we overtake appear to move as much slower.

Cleon. I imagine you would easily recollect how commonly those Positions are verified by Experience; and you will, at the same Time, make this natural Inference, that the swifter any Motion is, the less Time will be spent in passing over any given Space, and the slower the Motion, a longer Time will be required.

Euphros. This also is too plain to admit of any Hesitation; but what is all this to the Transit of *Venus*?

Cleon. These Things rightly considered, are so much to our Purpose, that they contain the whole *Rationale* of that great Phenomenon.

For (1.) If an Eye be placed at the Center of the Earth, (or any where on its Surface without Motion) then it is plain, if it views the Planet passing before the Disk of the Sun, it will see it move with its proper, or

real Velocity of Motion, so as to transit the Disk in about *seven Hours and Twenty Minutes*:——But (2.) If the Eye be placed on the Surface of the Earth, considered in Motion, then it is plain, that while the Globe moves on its Axes, those Parts of its Surface which pass under the southern Part of the Meridian moves in a contrary Direction to those which pass under the northern Part, with respect to any particular Point, or moving Body at a Distance in the Heavens: Thus in the Time of the Transit, you see on the terrestrial Globe, that all the Part of *Arabia* and the *Indies* move under the south Meridian from West to East, and those in *North America* at the same Time move (with respect to *Venus* upon the Sun) in a contrary Direction, viz. from East to West, under the northern Part of the Meridian.——And therefore (3.) it is plain, that since the Motion of *Venus* is from East to West upon the Sun, the Inhabitants of the *Indies*, who move in a contrary Direction, will view the Planet moving with a swifter Motion over the Sun than it really has; so that the Time of the Transit to them will be shorter than before, viz. it will continue about *seven Hours nine Minutes*:——But as the Inhabitants of *North America*, about *Hudson's Bay*, move the same Way with the Planet, she will appear to them to move slower, and therefore will be a longer Time in passing over the Disk, viz. about *seventeen Hours twenty-six Minutes*.

Euphros. Well, one would not imagine that the Nature and Theory of such important Doctrines depend on such trivial Observations as you mentioned; but I am thoroughly satisfied now of their Necessity and Utility.——But why does Dr. *Halley* delegate us to those distant Regions for viewing this Phænomenon; cannot the Philosophers do it as well at home as abroad? Those Climates are very different in their Nature, and may neither of them be agreeable to *English* Constitutions, besides the Danger, Difficulty, and Expence attending long Voyages.

Cleon. There are Reasons enough for his doing this, my *Euphrosyne*; the (1st) is, that such Places ought to be chose for the Observation, where the Beginning and End of the Transit can be seen; but the Beginning cannot be seen in any Part of *Great Britain*.——For once more turn the Globe about, to view those Places where the

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the Beginning is visible, and you will see the northernmost Parts of *Scotland*, the *Orkney Isles*, and even *Shetland* itself, all below the Horizon at that Time?

Euphros. I see they are; but how then am I to understand the Doctor, when he says, Perhaps the Ingress may be seen at Sun-rising by that very People who I now see are below the Horizon at that Time?

Cleon. I confess, I know not how to answer your Query, unless the Doctor supposes the Refraction of the Atmosphere is sufficient to elevate the Sun to their View, before it be really risen.

Euphros. The Reason which you have given is very sufficient for going to some one Place to observe the Transit; but why is any one Place, for Instance, *Bengal*, more eligible than another?

Cleon. The Doctor does not recommend *Bengal*, as more proper for the Observation than any other Place in the *East Indies*, but he mentions that in particular, as being an *English* Factory, and that particular Part of the Earth's Surface over which the Sun will be vertical at the Time of the Middle of the Transit: He represents it as an indifferent Matter, whether the Observation be made at *Bengal*, or Fort *St. George*, commonly called *Madras*, or at *Bencoolen*, on the western Coast of the Island of *Sumatra*, near the Equator: He also recommends *Pondicherry*, on the western Coast of the *Gulph of Ganga*, to the *French*; and *Batavia*, the famous *Emporium* in the Island *Java*, to the *Dutch*, as being very proper Places for observing the Transit, by the People residing there; and there is very good Reason for making as many Observations as possible, in the several Parts of the *Indies*, and as near the Equator as may be; because they will be there farther from the Earth's Axis, and observe the Transit to the greatest Advantage that can be, on that account.

Euphros. If those Parts are so advantageous, which are near the Equator, why then are not both the Observations to be made there, and so make one Trouble serve for all?

Cleon. You will easily see the Reason why that cannot be, by casting your Eye on the Globe? for if you now rectify it as you did before, for the Beginning of the Transit, you will find that the nocturnal Observation,

or that which is to be made at Sun-set, impossible in any less Latitudes than 23° North, and there only in the southern Parts of *California*, there being nothing but the great *South Sea* in all the Equator that can see the Setting-sun: Besides, suppose there was ever so fair an Opportunity of viewing the Transit at Sun-set, it would answer no Purpose, because it must necessarily be over before Sun-rising, the Length of the Night in all those Parts being much greater than the longest Duration of the Transit.

Euphros. You have thoroughly convinced and satisfied me in that Particular; I plainly see the Latitude for the second Observation must be such, where the Length of the Night is shorter than the Duration of the Transit; and as the Globe is now rectified, I can plainly see that among all the Places in *North America*, in the eastern Part of the Horizon, the first that offers itself for viewing the Transit at Sun-set is that which you mentioned, just now, viz. *Port Nelson*, at the Entrance of *York River*, all other Parts, or Places, being inaccessible to us; and, indeed, that is the first Place that will circulate below the Horizon, and rise again above it on the western Side before the Transit ends, and consequently will be the least Latitude in which we can observe the Duration of the Transit, including both the Beginning and the End. At the same Time, I understand now more plainly than before, why no other Places even in those northern Latitudes will answer for this Purpose, because they will necessarily be below the Horizon, either at the Beginning or End of it.

Cleon. That is very well observed, my *Euphrosyne*; for in the Island of *Great Britain* we lose the Beginning of it, and to observe the Time when it ends is not sufficient; and it happens very well for us, that *Hudson's Bay* provides us with this Port for the Purpose; for we should have found it attended with much greater Difficulty, to have had Recourse to Places in the frigid Zone: For tho' there are Places enough in *Lapland*, the northern Parts of *Russia*, *Nova Zembla*, *Iceland*, &c. where the Sun will not at that Time disappear, yet being near the Earth's Axis, the Difference between the Times of the Transit will not be so great, for an Eye placed any where in the

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Axis of the Earth will see the Transit of equal Duration; and therefore, to an Eye placed at the Center, or upon the Surface at either Pole, the Appearance will be the same in regard to Time, and this will lead us from the Globe to the Diagram, which I have provided for a farther Explanation of the Particulars of this Phænomenon, as they are to be astronomically considered.

Euphros. I cannot but think myself greatly obliged to you for your Care, in contriving every Way to facilitate the Knowledge of this uncommon Affair.——As to the Diagram, I can readily perceive at first View the Design of a great Part of it: Thus I observe, *A, B, C*, represents one half of the Sun, the Center of which is *C*, and the Diameter *AE*.——I imagine also, that the two black Circles on each Side of the Sun at *Y* and *Z*, represent the Planet just within the Sun's Disk in those Places; and farther, that *Y D Z* is the Path, or Track of *Venus* over the Disk:——Also, that *G, H*, is a Part of the Orbit of *Venus*, and that Planet in two Positions at *P* and *X*.——And, lastly, I suppose that the Circles *A F E G*, and others within it, may represent the Earth. Am I so far right, *Cleonicus*?

Cleon. You are, my *Euphrosyne*; the great Circle you mention is the Equator, the next Circle *B I D H* is the Parallel of $22^{\circ} 30'$ Latitude, answering to the Bay of *Bengal*; the inmost, or lesser Circle *c d e f* is the Parallel of 56° , answering to Port *Nelson* in *Hudson's Bay*; and *C* is the Center of the Earth, or Pole of the Equator, which you please.

Euphros. But what is the Use of all those Lines drawn from the Earth to the dark Planet on the Sun?

Cleon. These I shall point out to you in Order; and first, suppose an Eye was placed in the Center of the Earth in *C*, to view the Planet as it passes along in its Orbit from *P* towards *X*. it is evident, when the Planet arrives to the Point *S*, it would be seen just within the Sun by the Ray of Light *CSY*; and when it has advanced to the Point *V*, it will then be seen to touch the Edge of the Sun on the other Side, by the Ray *CVZ*, so that while the Planet describes that Part of its Orbit between *S* and *V*, it will appear, to an Eye at *C*, to pass over the Disk of the Sun from *Y* to *Z*.

Euphras. So far I apprehend you extremely well;—but, pray, what Time passes between the Beginning at Y, and the End of the Transit at Z, as viewed from the Earth's Center at C?

Cleon. You have been long, before now, instructed in the Measures of Astronomy;—you know the Diameter of the Sun is, at a Mean, a little more than half a Degree; but at the Time of the Transit, it will be very nearly 32' of a Degree: And therefore, supposing that the Diameter A E be divided into thirty-two equal Parts, the Planet will appear to pass over four of them in an Hour, *i. e.* her horary Motion is after the Rate of four Minutes an Hour; and therefore, in passing from Y to Z, the Time spent will be equal to about seven Hours and twenty Minutes; such will be the Time of the Transit, to an Eye at the Center C. In this Time a Spectator at the Equator will, by the diurnal Motion of the Earth, be carried through 110° of Longitude, equal to the Arch K F L.

Euphras. Very good, *Cleonicus*, I understand you; but now let me view the Transit from *Bengal*, in your Diagram.

Cleon. That you shall do; and for this Purpose you must suppose your Eye to be placed in the Point of the Parallel proper to that Place, to view the Beginning of the Transit at Y; which of Course will be on the western Side of the Globe, because in half the Time of the Transit you will be carried from *b* to I, where you will view the Planet in the middle of its Passage over the Sun at *D* nearly. From I you will be then revolved to (*a*) on the eastern Side of the Globe, to view the Egress of the Planet at Z; from whence it is evident, that the Beginning or Ingress will appear to you in the Line *b T Y*, and the Egress in the Line *a U Z*; therefore the Planet must be in its Orbit at T in the first Case, and at U in the latter; and, that its Passage from T to U, as it is shorter than that from S to V, so it will be performed in less Time, and therefore you will at *Bengal* observe the Transit of a less Continuance, than if your Eye was placed at the Center C.

Euphras. I think, I pretty clearly understand you; for I see the Motion from *b* towards *a* is in a contrary Direction

tion to that of the Planet from Y to Z, and therefore must cause her apparent Motion to be quicker, in the Manner you have now explained.

Cleon. As you cannot understand these Things too well, I shall exemplify it otherwise by the parallatic Angle, in a Case similar to that of the Candle on the Table, which I before mentioned to you : — Thus, suppose a Plane was placed beyond the Planet's Orbit in the Line rs , then when the Planet is at S, it will be seen on that Plane at v by an Eye at C ; but to an Eye placed at b , the Planet would appear on the said Plane at t , by the Ray $b S t$: So that the Planet in the same Point S will be seen in two different Parts of that Plane, by the Eye in these two different Positions, all which is occasioned, you see, by the Distance of the two Points C and b ; and the Angle $C S b$, or $t S v$, is what the Astronomers call the parallatic Angle, or that Angle which makes the apparent Difference of the Planet's Place : — From whence it is evident, that the less the Distance $C b$ from the Earth's Axis is, the less will be the parallatic Angle, and consequently in the Pole, where it vanishes, there will be no Parallax at all, as I observed to you before.

Euphras. I partly see the Reason of all that you now say ; and farther, if the Planet rs be taken away at the same Time that the Planet appears upon the Sun at Y, to an Eye at C, it will appear at a Distance from the Sun eastward at w , to an Eye at b , by the Ray $b S w$: — And lastly, that as we go nearer to the Equator, the Distance $C b$ will be greater, and therefore will occasion a greater Difference in the Place of the Planet, and Time of its Transit, and consequently will so much the better answer your Purpose. — But now for the Appearance at Port Nelson, *Cleonicus*.

Cleon. As your Motion is now to be considered in the same Direction with the Planet, you must conceive your Eye to be placed on the eastern Side of the Globe at c in the Diagram, to view the Ingress of the Planet at Y, which, it is evident, will appear by the Ray $c R Y$. — After this the Eye will be carried, by the Motion of the Globe, by the northern Part of the Meridian round to d , where it will view the End of the Transit at Z, by the Ray

Ray dWZ , and consequently the Time of the Transit at this Place will be all that is spent while the Planet describes the Arch RW (greater than SV), which will be about seven Hours and twenty-seven Minutes nearly, and is therefore longer than the Time of the Transit at *Bengal*, all which is occasioned by the Distance of the Points b and c from the Earth's Axis, and the contrary Directions in which they are moved.

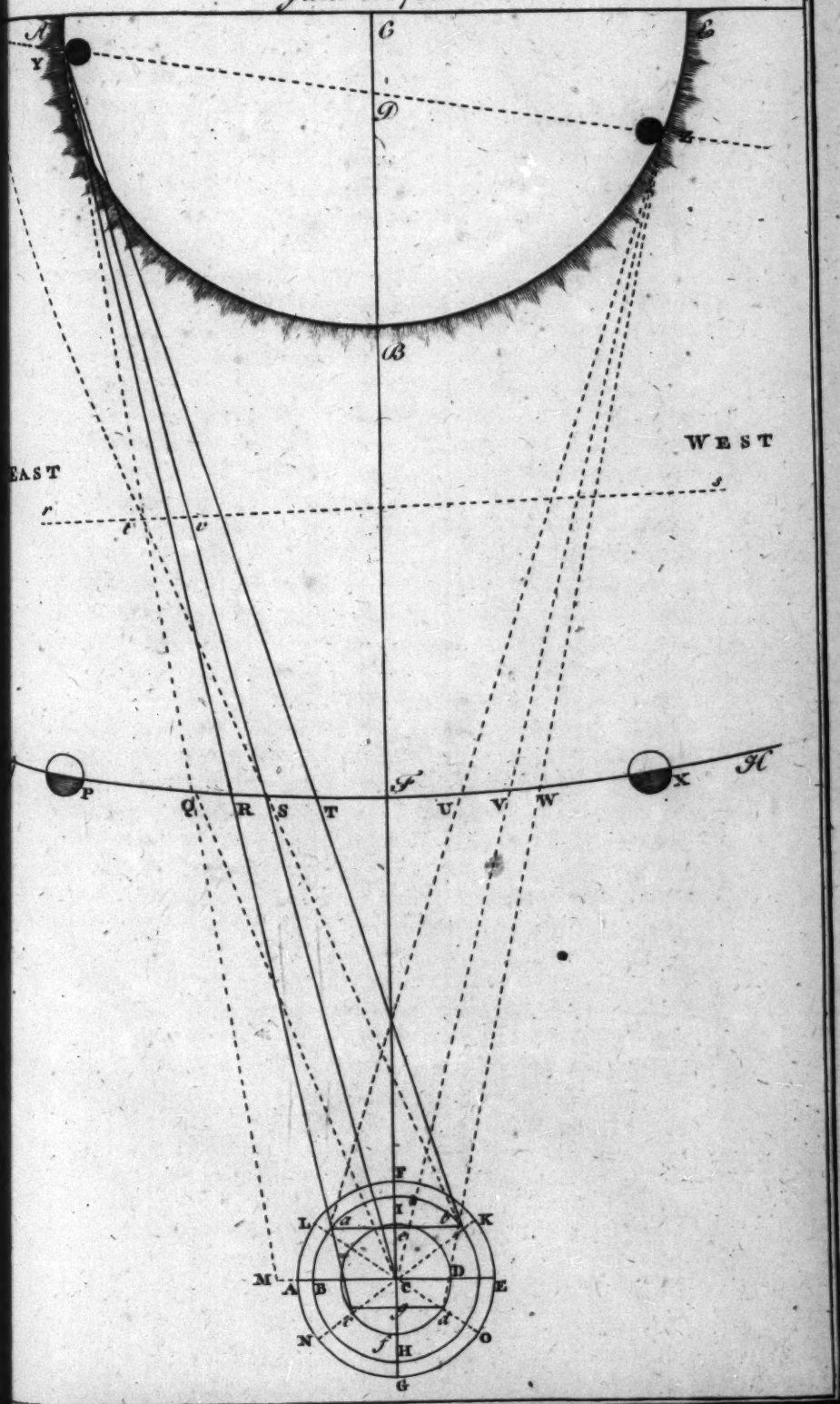
Euphros. I see nothing difficult to understand in all this; but how is this Difference in Times of the Transit applied, to finding the Parallax and Distance of the Sun?

Cleon. Very easily, by a Process in Trigonometry, as it requires nothing more than common Skill in the Doctrine of plain Triangles: But as you have not yet learned any Part of the Mathematics; I shall not pretend to trouble you with that Affair now; you will find it not difficult to understand hereafter.

Euphros. I shall gladly take another Opportunity of talking with you farther on this Subject; for though I have the Satisfaction to understand the general *Rationale* of this important Subject, from what you have now said, I am satisfied it requires still farther Reflection, and some mathematical Instruction, to understand it so compleatly as I could wish; for the acquiring of which, I shall be ready to devote any future Part of my Leisure.

Cleon. These Things, it is true, are much of a mathematical Nature, and therefore we shall at present proceed no farther in the descriptive Part.—But one Thing remains for you to know, and that is, a Method of shewing this Phenomenon in a most easy and delightful Manner, by Means of a new Apparatus adapted to the reflecting Telescope: And this shall be the Subject of our Converse at the next Interval.

the TRANSIT of VENUS over the SUN'S DISK June 6. 1761.



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DIALOGUE XVI.

The DESCRIPTION of a New SOLAR APPARATUS, adapted to the reflecting TELESCOPE, for shewing the TRANSIT OF VENUS over the SUN'S DISK, without darkening the Room.

Euphrosyne.

I HAVE ever since been mindful of your Promise, to entertain me with the Manner of exhibiting this curious and rare Phænomenon, by a new Apparatus applied to the reflecting Telescope. I hope this Morning will favour the Design, as the Heavens are clear and serene, and the Sun shines forth with its usual Splendour and Glory.

Cleon. We could not have wished for a finer Day than this is like to prove.—The Telescope I have chose for this Purpose is of the reflecting Sort, as it is most convenient to use for this Purpose, by Means of its Foot or Stand, the Construction of which is also different from the common Sort, and is thereby rendered more convenient for the Application and Use of this new Apparatus.

Euphros. I am not much acquainted with the Structure of those Instruments; but I plainly see a Difference between this and that which stands in my Father's Study, which I have often used to view distant Objects, and in which you have shewn me, before now, the Spots on the Sun's Face.

Cleon. That is a very good reflecting Telescope of the common Form; but this Telescope, which I shall now make use of, is much preferable for all the common Purposes of a Telescope in general, and it has many peculiar Advantages above the other, and of which they are not capable, as you will hereafter be fully sensible of, when we come to treat of the Nature and Use of this Instrument more directly.

Euphros. I observe this Telescope consists of two brass Tubes, and that the interior one is made to move backward and forward, by Means of a small Piece of Rack-work

work on the Side of the outer one : This, I presume, answers the same Purpose as the long Wire on the Side of the common reflecting Telescope, which we turn one Way or the other, for adjusting the Instrument to a proper Focus in viewing Objects.

Cleon. That is the Design of it in general ; but this Construction, as I said before, is much better adapted to our present Purpose, on other Accounts, than a Reflector of the common Form, though that will do very well.

Euphros. But what, and where is the new Apparatus you speak of ?

Cleon. I have not yet applied it to the Telescope, as I intend to shew you the several Parts of it in the first Place :—It is of a very simple Form, as it consists but of a few Parts, which I shall now proceed to describe.—
 (1). I take off the common Eye-piece of the Telescope, and screw on another in its Room, of a shorter or lesser Size. (2). I have adapted the common Candle Screen, made of black Silk, and which, in the usual Manner, expands itself into a circular Form, to the End of the Telescope, where you observe it is easily fastened on. (3). This square Piece of Brass, which is about six Inches and a half long, is screwed on to a Piece fixed upon the under Part of the Telescope. (4). Into the lower Part of this, another long square Piece of Brass is firmly fixed by Means of a square Shoulder, Nut, and Screw ; upon this is a Scale of Inches to the Number of thirteen. (5). Upon this long Arm is a moveable Socket of Brass, with a Screw to fix it to any Part, on the Top of which is a transverse Piece, into which are fixed two upright Wires of a proper Length. (6). Upon these Wires is applied a Screen of white Paper, of a circular Form, on which is drawn a black Circle of twelve Inches Diameter, divided into 360 Degrees, with two Diameters, one Vertical, and the other Horizontal. The first of these is divided into 1900 equal Parts, and numbered each Way from the Center 100, 200, 300, &c.*

* We apprehend the several Parts of this Apparatus are so plainly represented in the Print, as to need no Description by Letters of Reference.

Euphros. You will please to put them together, and then I shall have a more complete Idea of the Nature and Design of the Whole.

Cleon. This I shall instantly do:—First, I apply the Screen to the End of the Telescope;—then I screw on the perpendicular Piece of Brass;—into this I fix the horizontal Piece,—then I apply the Socket to No. 12, and there screw it fast;—after this, I apply this circular Screen to the upright Wires:—And then, lastly, I screw into the End of the Telescope the Brass Piece, containing the Magnifiers—and thus the Whole is fitted for Use.

Euphros. I see the Design of it is to form the Disk, or Face of the Sun, upon that circular Paper Screen;—but is not the Room to be darkened for this Purpose?

Cleon. No; the black Screen supercedes the Necessity of that troublesome and inconvenient Circumstance:—You will by Means of this Apparatus, in the most lightsome Room, have the Pleasure of viewing the Face of the Sun, and every Thing that may appear in or upon it, with as much Pleasure, and almost as perfectly as in the *Camera Obscura* itself.

Euphros. If this be the Case, it must render the Opportunity of viewing the Transit of *Venus* extremely easy and agreeable, in every Place where they shall be favoured with a Sun-shiny Morning, like this.

Cleon. And that this is the Case really I shall soon convince you by an Experiment or two with this Apparatus, and that in a different Way or Manner from any Thing that has hitherto been shewn of the like Kind: For all Objects that have been usually magnified in the solar Microscope, are represented in a Beam of the Sun's Light, very much dilated upon the Side of a Room or Screen; but here you will see Objects represented on the real Face, or the Disk of the Sun itself; so that by this Means we might properly make the bright magnified solar Disk the real Screen for shewing Objects upon; by which Means they will become vastly more vivid and distinct in all their Parts, and will make a much richer Appearance.——In order to satisfy you of what I now say, I shall, in the first Place, shew you the Face of the Sun upon the Screen, in various Degrees of Magnitude,

nitude, according to the Distance of the Screen from the magnifying Glafs, and you will always know the Diameter of the magnified Image of the Sun by the Number of Inches to which the Screen is placed on the Scale.

Euphros. That is, I suppose, if the Screen be placed at N^o 2, then will the Sun's Image be two Inches in Diameter; if at N^o 6, it will be six Inches in Diameter; and if the Screen be placed at N^o 12, then will the Solar Disk be 12 Inches, or just fill the graduated Circle.

Cleon. I perceive you have a very clear Notion of this Matter, and therefore shall preface no more concerning it, but shall proceed, in the first Place, to shew you the solar Disk, with the Spots upon it, if any; and accordingly.——First, I fix the Screen at N^o 1, and then directing the Telescope to the Sun, I turn the Pinion on the Side of the Telescope till I make the Sun's Face appear very distinct, and well defined on the Surface of the Screen, where it appears small indeed, as being now but one Inch in Diameter.

Euphros. Well, it is very curious to see the little Sun so very distinct:——I really can see two or three small Spots upon its Surface.

Cleon. Those Spots are not small, but large, as you will see when I move the Screen backward to N^o 4:—For now turning the Pinion, the Sun's Image appears very distinct, and just four Inches in Diameter, and the Spots appear now in Proportion larger and plainer.——I remove the Screen to No 8, there the Sun's Face is enlarged to eight Inches in Diameter.——Lastly, I place it at N^o 12, and by adjusting the Telescope, you there see the noble Appearance which the Disk of the Sun makes on the Screen, and just fills the graduated Circle drawn upon it.

Euphros. A glorious Sight indeed, and the Spots now appear to great Advantage.——This Method of viewing them is greatly preferable to that of poring through the Telescope itself at the Sun.

Cleon. As the Sun's Face and Spots are so easily and so distinctly observed, you will readily understand that the Planet *Venus*, in transiting the Sun's Disk, will be as distinctly represented and viewed.

Euphros. I can easily apprehend she will ; for when the Disk of the Sun itself is perfectly formed, the Planet *Venus*, as well as the solar *Maculæ*, must also be delineated in the same Degree of Perfection, by that exquisite Instrument.

Cleon. It will not be disagreeable to you, if I illustrate this by an artificial Representation of this famous Transit :——For which Purpose you must provide me with four of the smallest black Patches you can get.

Euphros. These I have at Hand, and will this Instant go for them :——These are the smallest I have ; will they answer the Purpose ?

Cleon. They will do very well ;——I have here an Ivory Slider, with a round Piece of Talk, on which I have drawn two Diameters, and likewise the Path of *Venus*, at each End of which I stick a Patch, and place the other two in the said Path, so that they may represent four Positions of that Planet on the Disk of the Sun, formed upon the Screen as before.——I put the Slider in its Groove, and then, by turning the Screw, you see those Patches gradually come to a perfect Form on the Face of the Sun :——They appear very black, round, and nearly in Proportion, as *Venus* herself will be seen in Comparison of the Sun.

Euphros. This is very natural indeed, as well as artificial.——I see *Venus* now at her Ingress and Egress, in the same Manner as she is delineated on the Print of the Transit at large ; and since this artificial Representation is so perfect, it will in a great Measure supply the Deficiency of the natural Transit, if the Weather should prevent our Enjoyment of that most desirable Sight.

Cleon. A Sight, that mortal Eyes never more than once beheld ! The famous *Jeremiah Horrox*, who lived at *Hole in Lancashire*, by his great Skill in Astronomy, foresaw and predicted the Transit of *Venus* over the Sun, *November 24*, in 1639. He gave notice of this to his Friend *Mr. Crabtree*, who attended him at the Time, and they both together in a darkened Room, where the Sun's Image was formed at large on a Screen, saw *Venus* just at nineteen Minutes after three o'Clock in the Afternoon enter the Disk ; but the Sun setting before the Transit was completed, prevented their having an entire View

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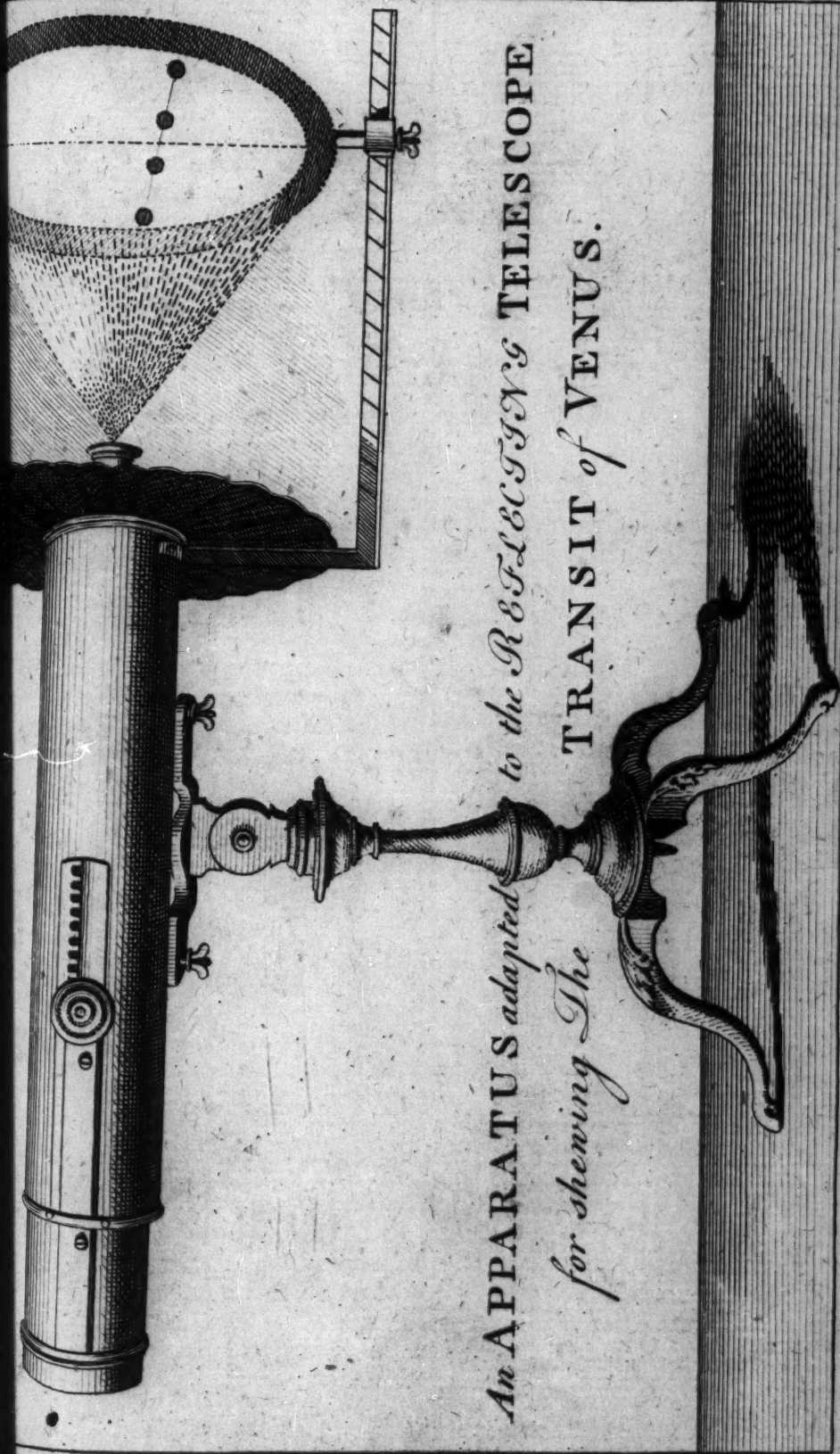
of it, so that this next Transit will be the first that will afford a View of the Phænomenon compleat.

Euphros. I should almost envy those Gentlemen the partial View they had, were not ours likely to be more compleat; for an entire View even at this next Transit, will be impossible, I find, to the Inhabitants of *Great Britain*:—But since the periodical Time of *Venus's* Revolution about the Sun is so short, I think it is a Wonder that we do not oftener observe her to transit the Sun's Disk.

Gleon. If you were very attentively to consider the Laws of the planetary Motions, the Wonder would soon cease. But I must refer an Explanation of this Matter to a future Opportunity.—I have informed you of every Thing I think necessary, relating to this Subject, for the present: The farther Use of this Apparatus, for magnifying Objects in the Nature of a solar Microscope, I shall explain to you at another Season, which will be very shortly: As our next Subjects of philosophical Conversation will be those of the Description, and practical Uses of the several Kinds of Microscopes, Telescopes, and other optical Instruments, which, I doubt not, will afford you as great Pleasure and Improvements as they have done to myself for many Years past.

The END of this PART.

An APPARATUS adapted to the REFLECTING TELESCOPE
for shewing The
TRANSIT of VENUS.



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CONTAINING
A PRACTICAL TREATISE on the Use of
OPTICAL INSTRUMENTS.

DIALOGUE I.

*On the Nature, Construction, and Use of SINGLE
MICROSCOPES*

Euphrosyne.

I HAVE spent all the Time I could conveniently spare, in looking over those Tracts which you recommended to my Perusal, preparatory to my understanding the Construction and Use of Optical Instruments. The Nature and Use of Optical Glasses are so familiarly described and explained by Figures, that I was at no Loss in verifying their several Properties by Experiments, which I made with the several Lenses and Mirrors you lent me for that Purpose.——I can now take any single Lens or Speculum, and therewith form the Image of any given Object at Pleasure.——I observe their various Magnitudes, in Proportion to the focal Distances of the Glasses ;——I see the inverted Position of each on the Paper ;——and if I fix the Glass, I make all those Images greater or less, by removing the Object nearer to; or farther from it.——I observe, with

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great Pleasure, what I think we may properly call the very Life or Soul of the Picture; I mean the natural *Motions* and *Colours* of every Part, the first of which no Paintings can pretend to, and the latter they but faintly imitate.——I delight myself so much with these philosophical Entertainments, that I wonder very much how so many of my Sex can be so easy and satisfied, without sharing with me in the Felicity which those Sentiments afford, arising from such an experimental Speculation of the Sciences.

Clecn. It is principally for want of such Speculations being *experimental*, that so many People appear indifferent about them. Matters of mere Theory are generally dry and jejune to any but those who have a particular Taste for the Subject; but the Science of Optics is conversant about such Subjects as are founded, not only in the most perfect Geometry of Nature, but are capable of being illustrated, and rendered in the highest Degree entertaining and useful, by the most easy and obvious Experiments.——This Science extends the Use of the Eye to an amazing Degree;—though this excellent Organ is by Nature constructed to produce the most useful Sensation, yet it is in a limited Degree: It is left to human Skill to perfect it in almost as much higher Degree as we please.——Whatever is necessary, Nature has supplied us with, in regard to Vision, with respect to the common Conveniencies of Life:——But if we would look far before us, and take a Prospect of the remote Scenes of Nature, and view her numberless Curiosities in her secret Recesses, we must make Use of the artificial Means of Vision, I mean *Optical Glasses* and *Instruments*:——And I don't know any Thing, in the whole Course of my Observations, that appears to me of so extraordinary a Nature as the great Estimation or Value we set upon common Sight, and at the same Time so little regard the *Improvements* of it.

Euphros. I fancy it must be in this Case, as in many others, what we don't perceive the Use, Pleasure, or Necessity of, we are not sensible, and therefore do not regard the Want of it; and a great many People appear to be naturally destitute of any Taste for the Refinements and Pleasures

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Pleasures arising from the Study or Extension of the Sciences, either Optical, or any other Kind.

Cleon. Your Observation is just ; to which I may farther add, that it is necessary it should be so, and that we ought not to look on those Things as any Faults or Deficiencies in Mankind : Those who want a Genius are not to be blamed on that Account, nor are we to wonder when we find them so frequently expatiating on the Pleasures arising from the Sensations of the *Gustatory Nerves*, and so little sensible of those of the *Optical* ones.——But to the Point : I have here brought you several *MICROSCOPES*, of different Forms and Constructions, on Purpose to acquaint you with the different Ways and Means that have been invented and contrived for their Application, in viewing *Minute Objects*. These the *Opticians* usually call *Single Microscopes*, and are to be held in the Hand.

Euphros. They seem to be curious Instruments, and neatly disposed in their Cases, with a Number of little Trinkets about them, all of elegant Workmanship.—I see they are of different Forms and Make, and I presume all answer one and the same End, *viz. to magnify any small Object* :——But one Query I must beg you to satisfy before we proceed farther, and that is, how it is in the Power of a Glass to make an Object bigger or less?

Cleon. The Glass, my *Euphrosyne*, can do no such Thing, the real Magnitude of the Object continues the same, however it may be viewed by the Glass, the magnifying Power, as we usually call it, is only apparent. The Eye, by Means of a Glass, views an Object under a larger Angle than it can do without, and consequently will see it, in Appearance, larger ; for by the Principles of Optics, which you have perused, if you recollect, it appears, that any Object subtends a larger Angle in Proportion, as it is nearer to the Eye, and that Angle is the Measure of the apparent Magnitude of the Object ; thus, for Instance, if you extend your Arm, and hold up your Finger against the Ball under the Cross, on the Top of *St. Paul's Cathedral*, it will appear much bigger than that Ball does, because it subtends a much greater Angle to the Eye than that Ball does at so great a Distance, though it be six Feet in Diameter.

Euphros. There is something very curious and surprising in your Doctrine of apparent Magnitudes, I find by Experiments, which I little thought of before; but admit that the Glass only shews the Object larger, yet there is one Thing farther that must be the Subject of another Query, *viz.* how it comes to pass that the Glass shews the Object distinctly at such a Distance from the Eye, where it cannot be seen without it, unless very confusedly?

Cleon. You will remember the Experiment which you made in the Sun Beams with the Glass, whose focal Distance was one Inch, *viz.* that it collected together the Beams into one Point, called the Focus; and that another Glass of the same Sort, held just as far beyond that focal Point, received the diverging Rays, and made them all parallel again.

Euphros. I remember it very well; but what do you deduce from thence?

Cleon. On that Experiment depends all the *Rationale* of Vision, by a single Glass; for the Eye is so formed by Nature, that unless Rays of Light fall nearly parallel upon it, they will not be converged to a Focus upon the *Retina* in the Eye, and therefore no perfect Image can be there formed, but by those Rays which come from Objects so far removed from the Eye, that they may be considered as nearly parallel; and therefore, as I said before, there is a Limit to perfect Vision by the naked Eye, and this you will find in general to be about six or seven Inches from the Eye, with regard to near Objects: This is confirmed by Experience, because any Object held nearer to the Eye will appear confused, as the Rays coming from any particular Point must be considered in a converging State, and consequently tend to a Point or Focus beyond the Bottom of the Eye, and therefore the Image must be very imperfectly formed on the *Retina*, and so produce a confused Appearance of the Object:—For Example; I hold a Piece of Wire at three Inches distant from my Eye, and it appears large, but very confused and indistinct; but if I take a Glass, whose focal Distance is three Inches, and hold it close to my Eye, the Rays will by that Means be made to fall upon the Eye in a parallel Direction, and by that Means be nicely
united

united on the *Retina*, and there forming a perfect Image of the Wire, will cause a distinct View of it.

Euphras. I seem to have a tolerable clear Idea of this Matter:—And since the Wire appears distinctly at the Distance of three Inches from the Eye, by Means of the Glass, it will be seen of Course under an Angle twice as large as it subtends to the naked Eye at the Distance of six Inches, and therefore will appear twice as large; consequently, an Object in such a Case may be said to be magnified twice.—For the same Reason it will follow, that if a Glass of one Inch focal Distance be applied to the Eye, the Object in that Case must be placed in its Focus, or at one Inch from the Eye, and then the Rays being rendered parallel upon the Eye will cause a distinct View of it at that near Distance, which, as it is six Times less than six Inches, it will appear so many Times magnified by such a Glass.

Cleon. What you have now said, you instantly prove by Experiment; and the same Reason holds for any Glasses of shorter focal Distances, they always magnify more in Proportion.—But let us reflect a little on the magnifying Power of a Glass, whose focal Distance is one whole Inch:—You see it magnifies the Diameter of the Wire six Times; but as you increase the Length or Breadth of an Object, the Surface will increase in Proportion to the Square thereof, and consequently will appear six Times six, or thirty-six Times as large as it appears to a naked Eye, and consequently such Glasses will exhibit a very agreeable View of many of the larger Kind of small Objects; for which Reason they are very much in Use, in observing the Works both of Nature and Art, and may be properly called MEGALASCOPIES:—Thus all the smaller Sort of Flowers appear extremely fine when viewed through such Glasses.—All Kinds of Insects, as Flies, Bees, Wasps, &c. make a noble Appearance thus magnified, and seem quite different Creatures than what they appear when viewed diminutively with the naked Eye.—The Texture and Vessels of Plants and Animals are exquisite Subjects of the Megalascopes;—and when we apply them to view the Works of Art, their Benefit is sufficiently known to the Watchmaker, the Draper, the Engraver, &c. under the Denomination

of the *Watchmakers-Glass*; *Cloth-Microscope*; &c. and or a pretty Experiment of this Kind, I need only propose to you this small Circle, in which is contained the ten Commandments, which the best of Eyes cannot decypher, but with a Glass you see to read the whole distinctly.

Euphros. This Glass is of excellent Use, I find by this Experiment; and this, which you have been so kind as to make me a Present of, will afford me great Entertainment, as I shall frequently apply it to the Purposes you have mentioned.

Cleon. There is one Thing farther to be considered, with regard to the magnifying Power of this Glass, viz. that the Solidity, or the whole Bulk of a Body is magnified in Proportion to Cubes of the Diameter or Side: Thus, suppose any Globule, or other small Object were to be viewed through the same Glass, the whole Bulk will be apparently increased six Times thirty-six, or 216 Times, or so much larger it would appear through the Glass to the naked Eye.—I have brought with me two or three Marsh-mallow Flowers for a Specimen of this Kind; you see a little white Part standing up in the Middle; pray, view it with your megalascopic Glass, and tell me what you see.

Euphros. I see a great Number of very beautiful, small, white Globules beset with thick Bristles, and growing in Clusters at the Tops of long white Stalks; a most agreeable Spectacle this, and what I could never have thought of from the naked Eye.

Cleon. As another Instance, take this Leaf of Sage, and view it with the same Glass.

Euphros. I do; and am amazed to see the numberless Globules all over its Surface, in Appearance like small white waxen Balls;—others upon the Mint Leaf I see have a different Appearance, but require to be magnified still more to view them perfectly.

Cleon. That you will do by and by; I only propose by these Specimens, that very small Objects, when magnified 200 Times, are capable of being seen even with a Megalascopé:—And were you to see a Flesh-fly 200 Times as large as what you view with the naked Eye, they would command your Attention as much as a Crocodile from the River Nile, which is but a Lizard of a larger Bulk.

Euphros. Pray, of what Form or Size are those Glasses which you make use of for greater Powers of magnifying?

Cleon. They are of the same Form with this Megalafcope Glas, viz. a double Convex generally, but the Size very small; for as they are intended to view small objects, there is no need of a large Diameter, nor indeed will the Nature of the Glas admit of it:—As the Glasses are small, so are their focal Distances, and in Proportion their magnifying Powers the greater; hence these Glasses are properly called MICROSCOPES, which denote only their Power of *magnifying very small Objects*: But as these Glasses are so very small, they cannot conveniently be applied to Objects without being adapted in a Frame, consisting of proper Parts for that Purpose, by which Means the Glas and the Object may be at any required Distance from each other, and from the Eye, and the Object viewed with all imaginable Ease, by holding them in the Hand against the Light, as you will easily see in the several Forms here before you, which indeed are but four, but they are the best and most convenient of all the numerous Inventions for this Purpose.

Euphros. Which of those Microscopes do you recommend as the most perfect and eligible?

Cleon. It is difficult to say which is the best of all; they have severally their peculiar Advantages arising from their particular Form, and the Apparatus proper to each.—Some Gentlemen prefer one Form, some another; and I will point out the Properties of each separately, that you may chuse upon Occasion which you please, for I shall make you a Present of them all.

Euphros. In this you will highly oblige me, indeed; but you must, in the first Place, make me acquainted with the Use of them, for there are so many small Adjuncts in what you call the Apparatus, that unless I know the Use of each Particular, I shall not be perfect in the Application of the Instrument.

Cleon. It is very true, my *Euphrosyne*; I know it is incumbent upon me, in the first Place, to dissect, as it were, each Microscope, and shew the Use of the several Parts as they are variously applied for viewing different Objects. The first I shall begin with, is that which

generally goes by the Name of WILSON'S MICROSCOPE. though the first Inventor of this Form is perhaps not known. This Microscope consists (1.) of an external and an internal Tube, the latter moving by a long Screw in the former; the external Tube being for the greatest Part open on each Side: You observe (2.) two thin brass Plates moving regularly in that Aperture by the Motion of that internal Tube or Screw; and to keep them together you see (3.) a spiral Wire bear upon them from the End on the Inside of the outer Tube, the Intent of which is to press those Plates firmly together. (4.) The several Ivory Sliders which you here see numbered, 1, 2, 3, 4, &c. in which are contained the several small Objects placed between two thin Plates of *Muscovy* Glass, usually called Talks; besides these there is (5.) this long Brass open Frame, to which is fitted an Ivory Slider, containing small Concave Glasses, with a plain Slip of Glass placed over it for inclosing any minute living Object without crushing it; this likewise, when used, is placed between the two thin Plates, below which is (6.) a third Plate or Piece of Brass with a cylindric Hollow to receive (7.) the several glass Tubes, which you here see, three in a Set, contained one within another, for holding any Fluids with Animalculæ, Tadpole, Water-Newt, small Frog, &c. for shewing the Circulation of the Blood. (8.) At the End of the outer Tube is a Hole, with a Screw, to receive the several Plates of Brass, or Buttons, which contain the small magnifying Glasses. (9.) At the external End of the inmost Tube is a Plano Convex Lens, to throw Light upon the Object on the Sliders, (10.) Over this Glass are placed circular Pieces of Brass, with Holes or Apertures of a different Size, for proportioning the requisite Degree of Light. These are the principal Parts to be used in viewing transparent Objects: But for those that are opaque, you are supplied with the following Apparatus. (11.) A square, flat Piece of Brass, with a bevel Edge on one Side, and pierced with a Hole through the Middle, with a small Steel Spring to bear upon (12.) an Iron Wire, made sharp at one End, and containing a Pair of Pliers on the other; this Piece of Brass with the Pliers, being placed between the two thin Plates of the Microscope,

there

there is (13.) another Piece of Brass with a Screw at one End, by which it is fixed on the object End of the Microscope on one Part, and contains on the other a hollow Screw for receiving the several Magnifiers, which, in this Case, shew any Object held in the Pliers at one End, or fixed on the sharp Point at the other; and to adapt every Glass for this Purpose, this Piece consists of two Parts, with Motion about a Center. (14.) On the sharp End of the Wire there is screwed on a small circular Piece of Ivory, with one Surface black and the other white, on which Objects of a different Colour are laid to be viewed. (15.) Instead of the small Glasses, you may screw on the Glass in this black Ivory Frame, which is called the Tun: This is designed for viewing larger Objects, like that which you have in your Pocket. (17.) A Pair of Nippers, Hair-Brush, Box of Talk-wires for fixing them in the Sliders, &c. complete the Apparatus of a *Wilson's* Microscope, for viewing every Sort of Objects*.

* That the Reader may have a proper Idea of the four different Forms of single Microscopes, and the principal Parts of the Apparatus, we have thought proper to add a Figure of each Form, drawn from the Instruments themselves, which need no particular Description, as the Uses of the several Parts may be easily understood by Inspection. (See Plate XLIII.) The Particulars of the Apparatus are as follow:

A is the Megaloscope Glass, to be held in the Hand for viewing the larger Sort of small Objects.

B the circular Piece of Brass, in which the Microscopic Glass is placed to be screwed on at the End of *Wilson's* Microscope, or that of the first Form; of these there are 6 in Number.

C a Pair of Nippers for taking up small Objects.

D a Quill with a Camel Hair Brush at one End for cleaning Glass, and a Pen Point on the other for taking up a small Quantity of a Fluid, &c.

E a Glass Tube for holding Fish, or other Animals, for shewing the Circulation of the Blood.

F a long Brass Case for holding a Slider, with small Con-
caves, and a plain Glass over them for confining small living Animalculæ.

G a small Box of Talk and Wires, for supplying the Ivory Sliders upon Occasion.

H

Euphros. You have run over a large Catalogue of Particulars indeed ; one had need have a pretty good Memory to retain the particular Uses of each : But I apprehend this will not be difficult after a little Practice.

Cleon. You will find it extremely easy to manage every Part with once using only ; and when you know it in one Microscope, it is nearly the same in all the rest, which differ from each other principally in the different Manner of applying the several Parts of the same Apparatus.

Euphros. You will please, in the next Place, to inform me of the different Power of magnifying belonging to each Glass of the Microscope, that I may have a more adequate Notion of the Effects of this Instrument when I use it.

Cleon. This cannot be known without measuring very precisely the focal Distance of each Glass : Thus, for Example, I find by measuring, that the focal Distance of this Glass is *one Tenth* of an Inch ; Now, you know that in 6 Inches there are 60 Tenths, and consequently, when I view an Object through this Glass, it is then 60 Times nearer to my Eye than when I view it without the Glass, and therefore it will appear 60 Times larger in regard

H a Piece of Ivory with two Sides, the one black and the other white, with two small Steel Springs for holding Objects upon them-

I the Silver Speculum belonging to the opaque Microscope, or that of the third Form, in the Center of which the small Magnifier appears.

K a double Spring Frame for holding the Glass Tube.

L the same for an Ivory Slider.

M two small circular Pieces of Brass, containing a concave and a plain Glass, one moveable over the other, for confining small living Objects.

N the Plyers, in the Position they are applied for viewing Objects in the Opaque Microscope, to the Point of the End of which below are screwed on the several Parts of the Apparatus, denoted by the several Letters H, K, L, and M.

There are other Particulars of an Apparatus belonging to these Microscopes ; but as they are seldom used, and the Manner of their Application not easily understood without viewing the Instruments themselves, we have here omitted their Representation.

regard to Length and Breadth. Thus a Flea, or any small Animal, will appear 60 Times longer and wider than it does to the naked Eye; and, because a Flea is much about $\frac{1}{10}$ of an Inch long, it will appear through the Glass 6 Inches long.

Euphros. What an hideous Figure must it make of that monstrous Size!

Cleon. Especially if you consider that the whole Surface of the Body of the Flea will appear 60 Times 60, or 3600 Times larger than we view it with the naked Eye.

Euphros. Heavens! why, at that Rate, it must appear as large as a Lobster.

Cleon. I can assure you, the Comparison is very *apropos*; for, when the Flea is thus magnified, it has very much the Appearance of that testaceous Animal, as you will see by and by.—But add to this, that the whole Bulk of the Flea will be magnified 60 Times 3600, or upwards of two Hundred Thousand Times, and so much larger it will appear through this Magnifier, than to the naked Eye*.

Euphros. Prodigious, indeed! I must be strangely delighted with such unusual and extraordinary Views. If small Animals are magnified to that extreme Degree, how wonderful must it be to view the Mites, and other small Animals, which appear in such very great Numbers?

Cleon. They appear more numerous to the naked Eye, than through the Microscope; for in Proportion as they are magnified more, the less in Number will be seen; and notwithstanding this Glass which I have now mentioned has so very great a magnifying Power, there are others which still much more exceed it, and other Methods of magnifying, besides directly poring through the Glass, by which Means a Mite will be shewn as large as a Porcupine; and Animalculæ, when magnified Millions of Times, will appear scarce larger than physical Points; all which you will be satisfied about in a very little Time, by ocular Demonstration.

Euphros. To tell you the Truth, I cannot help being in very great haste to see them; therefore hope you will not detain me long from such wonderful Speculations.

* At present we refer the Reader to the Print of the Flea. See Magazine for April, 1759.

Cleon. As I have largely described to you the Apparatus belonging to Microscopes in general, what remains, in regard to the particular Construction, and Manner of Application, will be dispatched in a few Words. In respect to the Manner of placing the Glasses, you observe, it is different in each of the three Forms; for, first, in *Wilson's* Microscopes the Glasses are properly set in circular Pieces of Brass, which are separately screwed on to the Body of the Microscope, for viewing Objects, and they are adjusted to a proper focal Distance by Means of a Screw.

But, secondly, the newest Invention for this Purpose, is to place all the Magnifiers in one long Piece of Brass, by which Means it is easy to apply any Glass to the Object, instantly, without the Trouble of screwing the Glasses on and off the Microscope; also, the Focus is immediately adjusted by the Contrivance of Teeth and Pinion, which you here observe on the Side of a Microscope of this second Form.

Thirdly, in order to view Opake Bodies by the single Microscope, there has been lately contrived a Method of applying the Magnifier to a Hole made in the Middle of a reflecting Silver Speculum; which Speculum being screwed on to the Instrument, the Opake Object in the Pliers is placed before the Magnifier, and the Light strongly reflected upon it to render the superficial Parts delightfully visible. The Focus is adjusted by a Brass Piece, moveable by a Screw and Spring, as also by the Joint of the Pliers. In this Contrivance, all Kinds of Objects, both Transparent and Opake, are most advantageously viewed by Means of a single Magnifier.

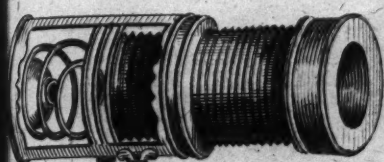
The three Forms, now mentioned, are properly called *manual Microscopes*, as they are all of them held in the Hand, and turned to the Sky-light, or Candle, in viewing Objects.

But there is yet another, and (in some respects) a more commodious Form of a single Microscope, which is placed on a Foot or Pillar with a moveable Stage, on which the Object is placed; below which is placed a reflecting Speculum, moveable every Way to throw up the Light on the Object; and this we may call the Fourth, and last Form of a single Microscope.

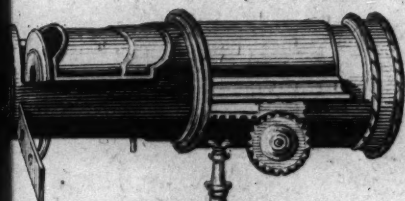


ifferent FORMS of Single MICROSCOPES.

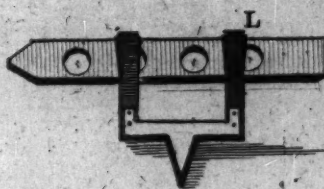
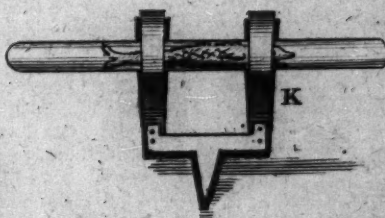
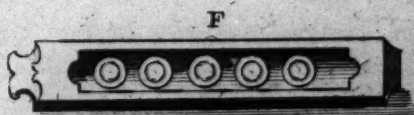
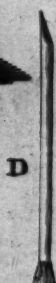
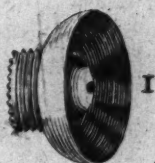
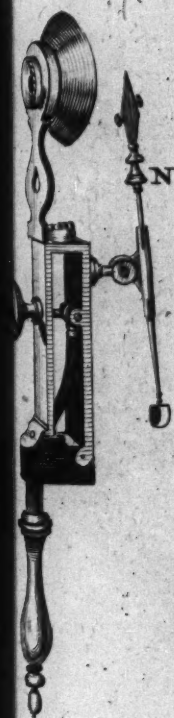
Plate XLIII.

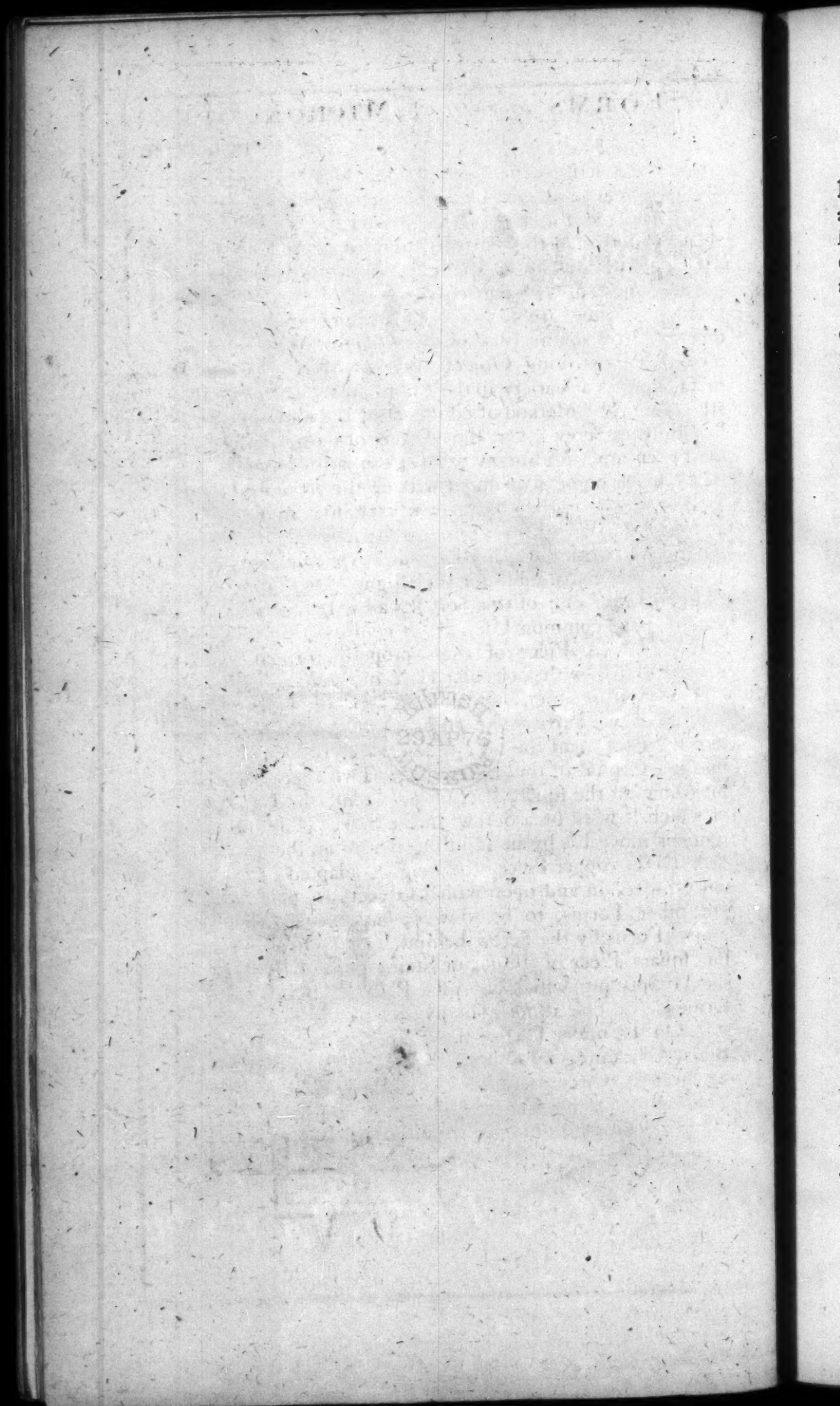


First Form.



Second Form.





Euphros. I think this appears to be the most convenient Method of them all, as I have nothing to do but only fit at the Table and look through the Glafs at the Objects.— But I see, that in this Sort of Microscope you have different Constructions; for I take it, that all these before me are Specimens of each particular Form.

Cleon. They are so; and I have procured them, in order to give you an Idea of the different Manner of applying, and viewing Objects in this Way. In all of them there is a Variety in the Frame in which the Glasses are placed, the Method of constructing the moveable Stage by adjusting Screws, &c. the Manner of fixing the reflecting Speculum, and many other Peculiarities, which you will easily become acquainted with in the separate Use of each.—Some of these are very expensive in regard of curious Workmanship:—Others, too much laboured and incumbered with too many Parts and Appendages:—And others are as remarkable for their light, easy, and elegant Construction: one of this Sort I shall here recommend to you for your common Use; and it consists of the following Parts: (1.) A Piece of Brass properly formed for the Foot or Basis, with a circular Hole in the Middle, whose Use I shall mention hereafter. (2.) The Stem, which consists of two Parts: The 1st of which is a Pillar screwed into the Foot, and the 2d a square Piece of Brass screwed into the Capital of the Pillar. (3.) Two Pieces of Brass, moveable on the square Part of the Stem, the Lowermost of which is fixed by a Screw in the Side, while the other remains moveable by an adjusting Screw on the back Part. (4.) To the upper Piece, the Stage is adapted by a Dove-tail Groove, in and upon which Objects are placed, as in the other Forms, to be viewed, and are adjusted to a proper Focus by the Screw behind. (5.) On the Top of the square Piece of Brass, or Stem, is fixed the Head of the Microscope, which has a flat Piece of Brass, properly formed, and placed horizontally and parallel to the Stage. (6.) On the under Part of this Plate is a circular Piece of Brass, containing 6 Glasses, disposed in a circular Manner near its Circumference: This Piece is moveable on a Screw-pin in its Center. (7.) On the upper Part of the Head-piece is another circular Piece of Brass, fixed at the End with a Screw on the Outside, and a small Hole

Hole in the Center, to which the Magnifiers are successively applied for shewing the Objects on the Stage below. (8.) The reflecting Speculum, screwed on to the Pillar, and moveable on a Joint, illuminates the Object to be viewed.—From all which, you will readily see how easy and pleasant it must be to view Objects in this Construction of a Microscope. There are many other Ways and Methods of applying single Glasses, but none of them so well deserve your Notice, as the four different Forms I have now described to you : But I must take another Opportunity of explaining to you the Difference between single and compound Microscopes ; the different Construction of the latter,—and, last of all, the Nature and Construction of the Solar Microscope, which must be the Subject of our ensuing Microscopic Speculations*.

DIALOGUE II.

Of the Nature, Construction, and Use of COMPOUND MICROSCOPES.

Euphrasine.

AT our last Interview you entertained me with an Explication of the different Forms and Construction of single Microscopes, and promised me, in our next, the same Thing with regard to compound ones ; and I see, by the Instruments before me, that you intend to be as good as your Word. — They are equally numerous, and much exceed them in Magnificence of Appearance ; but, I fear at the same Time, since they are not so simple in their Nature as the former, their Construction and Effects will not be so easy to be comprehended.

Cleon. When you see the Parts of which they are composed, you will not find them so very complicated as you imagine ; and tho' they strike the Eye with Grandeur and Sumptuosity, yet the essential Parts, by which the Effects are produced, will be found to be very few, and those easy to be understood.

* See Plate XLIV.

Euphros. I hope I shall find it so ; but, pray, is the Effect of a compound Microscope above that of a single One, in any Proportion to its Magnitude ? if it be, they must be wonderful Instruments indeed.

Cleon. In answer to that Query, my *Euphrosyne*, I need not inform you, that your Sex, as well as our own, are very apt to be affected with Grandeur and Magnificence, in every Shape ; and the Microscope, to many People, as much recommends itself by a pompous Appearance, as by its useful Effects : But as we are only at present concerned with the latter, I shall proceed to shew you the Difference between a single and compound Microscope, which consists in the following Particulars : (1.) In the single Microscope one Glass only was necessary, because the Object itself was viewed by that Glass ; but (2.) In a compound Microscope the Image of the Object is viewed by the Eye, and therefore two Glasses at least are necessary in this Construction, *viz.* one to form the Image of an Object, and the other to shew it magnified.

Euphros. Then I apprehend, by what you have said, that only two Glasses are essential to a compound Microscope : But besides the two which you have now shewn me, I observe there are two others in the Instrument ; pray, to what Purpose do they serve ?

Cleon. They only serve to make Vision more distinct and pleasant, by properly attempering the Rays of Light, and enlarging the Field of View. The original Construction was with the two Glasses only ; then a 3d was added, for an Improvement of the Invention ; and, at last, a 4th, to complete that Improvement.—It requires a mathematical Skill in Optics, to conceive the *Rationale* of them all ; but you will easily find, by Experiment, that they have each of them their peculiar Uses, in producing the great Effect of a magnifying Power in the best Manner possible.

Euphros. You will be so good as to point out to me the Uses of each particular Glass, and illustrate the same by an Example.

Cleon. That I shall readily do, with an Object a little in your own Way, I mean, a Row of the smallest Minikin Pins, which you can give me ; and you will be no less pleased with the Oddity of their Appearance, than you are with their Uses in Dressing.

Euphros. This Experiment will be very *a-propos*, indeed.—Here is a Row of the fine Pins you want.

Cleon. The Glasses of the compound Microscope are all contained in one Part, which is called the Body of the Microscope, the lower Part of which is a long Pipe, or Snout, as it is commonly called, on which is screwed a Brass Button, or Box, containing a small magnifying Glass, which of itself has a considerable magnifying Power, as will appear by your applying the Row of Pins to the Focus of that Glass, which I have now taken off for that Purpose.

Euphros. Well; how oddly they appear, indeed!—they look as large as Corking Pins:—Their Heads as large as Bullets, rough and uncouth.—There appears just five in the Field of View.

Cleon. By that you will know the Uses of the other Glasses; for if now I screw that on to its proper Place, at the End of the Pipe, and take off the Glasses on the upper Part, then, by placing the Body in the external Part, or Case of the Instrument, I move it gently down towards the Pins that are now laid upon the Stage, and by adjusting the Glass to a little more than the focal Distance from the Object, the Image of the Pins are formed in the upper Part of the Body, as you will easily see by placing this Piece of oiled Paper in the Focus of the large Glass.

Euphros. I see the Image very plainly formed upon that Paper; and they appear this Way as large as in the other, or through the Glass itself.

Cleon. The Image (as you learn from the Principles of Optics which you read) is as much larger than the Object, as its Distance is greater; and since the Distance of the oiled Paper from the Glass is 6 Times as great as that of the Paper of Pins, therefore you see the Image of each Pin 6 Times in Diameter and Length greater than it appears to the naked Eye, from whence you understand that, by this single Glass alone, the Object is magnified 6 Times:—Then, if this Image be viewed by another Glass, which you see here on the Top, of one Inch Focus, and therefore placed just one Inch above the oiled Paper, the said Image will appear very distinctly to the Eye; and since, in this Case, it is at least 6 Times nearer

to

to the Eye than it can be seen without the Glass, therefore the Image will appear 6 Times larger, by Means of the upper Glass than it does to the naked Eye; and, consequently, the Object will appear 6 Times 6, or 36 Times magnified in Length and Breadth, and the Surface is magnified 36 Times 36, or 1296 Times, and in Solidity 36 Times 1296, or 46656 Times: And in that Degree you must understand the Heads of the Pins are magnified, as they are solid Bodies.—I will now put the Glass in its Place, and then you may see the Experiment.

Euphros. They are magnified to a prodigious Degree, I allow; but still I cannot conceive they are magnified Forty-six thousand Times.

Cleon. There are no Fallacies like those of Vision, on the one Hand, nor any Truths so much suspected on the other: We often see Things that are not, as if they were, and cannot easily be persuaded to the contrary; and no less frequently we look upon real Facts as the greatest Improbabilities.—This shews, in general, how necessary the Knowledge of Geometry and natural Philosophy is, to give People a just and adequate Idea of Things, and to free them from all Imposition by their Senses, as well from optical as all other Kinds of Illusions — Thus much for the magnifying Power of the two Glasses, which greatly exceeds that of the single Glass alone.

Euphros. But another Thing I observe, *Cleonicus*, is, that though the Pins be much more magnified by the two Glasses, yet I observe not so many of them: for now, scarcely 3 appear instead of 5.

Cleon. This is only the common Consequence of magnifying; for the more any Object is magnified, the less Number or Quantity of its Parts appear: And it is for this Reason, that this other larger Glass (called the *Body Glass*) is added, to enlarge the Field of View, by diminishing the magnifying Power of the two Glasses; for when I put this Glass in its Place, you will see the Image is contracted on the oiled Paper above it, and by that Means a larger Quantity of the Object will be depicted upon it, and consequently a greater Number of Pins will appear, as you will find by trying the Experiment.

Euphros. This I clearly see;—but then one Question will occur, which is this: you tell me, that one of those

Glasses on the upper Part is employed to magnify, and the other to diminish the Image formed by the small object Glass; since this is the Case, is it not possible for one Glass to answer the End of both; that is to say, to magnify just so much of itself as they both do together?

Cleon. I answer in the Affirmative, one Glass will magnify just as much as the two; but there is another Purpose to be answered besides the magnifying Power, and enlarging the Field of View, and that is, to correct the Errors of Refraction by a single Lens, and to make the Field of View more perfect towards its extreme Parts, so that the Objects which lie round the Circumference appear less distorted and confused than in an equal Field by a single Glass only: And moreover, the Rays of Light, passing through both Glasses, are so attamped, and, as it were, adjusted, that the Cone of Rays entering the Eye, render the Vision more easy, steady, and pleasant*: All which you will easily find by observing the Object through both Glasses, and through one alone, when the magnifying Power is in both Cases equal. And what I have observed now with respect to the Eye-glass, is equally applicable to the Object-glass below; and therefore, when refracting Microscopes are constructed with four Glasses, they are then as perfect as the Nature of such Instruments will admit of, and such a one I have here put into your Hands.

Euphras. The Microscope, which you have been now so kind as to make me a present of, is of a superb and magnificent Form; and having so large a Bulk, I apprehend the Field of View, and consequently the Use of the Instrument, will be so much the more perfect and pleasant.

Cleon. In this you may, perhaps, be in some Degree mistaken: It does not follow, that the Field of View is always proportioned to the Largeness of the Instrument, or Glasses; there is a Mean in all Things, or Limits, which, as your HORACE tells you, are the Bounds of Perfection,

* The Theory, or Rationale of this Doctrine of the Composition of Glasses, and of distinct and indistinct Vision, is fully and particularly explained in my new Principles of Achromatic Optics.

Perfection, on either Side of which it is impossible any Thing should be right.—You will wonder, perhaps, when I tell you, that a compound Microscope may be constructed not more than an Inch in Diameter, which will shew you most Sorts of Objects nearly as well as this large one of two Inches : And to convince you of this Truth, I have provided likewise a compound Microscope of a portable, or pocket Form, that you may take with you into the Gardens, or Fields, for instantly viewing any Object that may present itself in your Walk.

Euphras. You are very obliging, *Cleonicus* ; it seems to be a pretty, neat Instrument for that Purpose.—I observe, there is the same Number of Glasses in this as in the large One, and when I put the Row of Pins under, they appear, as you say, very nearly the same as in the larger Microscope, and must consequently afford me a Variety of optical Pleasures from the Multiplicity of Objects which the Fields and Gardens afford :—But, methinks, I should be glad to know somewhat of the Reason, why those small Glasses perform so nearly as well as the large ones ?

Cleon. The general Reason will appear from considering, that the Perfection of the Image in all the Variety of optical Instruments is regulated by the Aperture, or round Hole, by which the Light passes through the Glasses from the Object ; on which account we are obliged to have strict regard to this Aperture of the Object-glasses on two Accounts ;—the *first* is, because the less the Aperture of the Glass is, the less will be the Error of Refraction, and consequently the greater will be the Perfection of the Image formed of the Object.—But, *secondly*, if the Hole be too small, the Image will not be sufficiently bright, and therefore the Aperture must be such as will admit of a sufficient Degree of Light, by which the Picture of Objects may be viewed to Advantage : Therefore the Perfection of the Instrument principally depends on the Aperture, and not on the Size of the Object-glasses, which you see is the same in the large and small Microscope.

Euphras. This, I observe, and am very well pleased that you have mentioned this Particular, which I might not otherwise have so well considered ; as to what regards

the Errors of Refraction, I must take that upon your Word : But I can readily apprehend, that if the Aperture of the Object-glass be too small, or too large, there will certainly be too little, or too much Light for shewing the Object with a requisite Distinctness and Perfection : and there is as little Pleasure in viewing the Image, tho' well defined, in the Dark, as there is when confused with too much Lustre.—But though the Object-glasses are alike in the Parlour, and the Pocket-Microscope, yet I see the Eye-glasses are widely different, being very large in the one, and small in the other ———

Cleon. It is true, they are ; yet the Effect is nearly the same in each : And to convince you of this, I shall shew you the Hole in that Piece of Wood which is usually called the *Stop*, which is placed between the Eye-glasses, and which is but a Trifle bigger in the large, than in the small Microscope, as by screwing off the upper Eye-glass you will discern very plainly.

Euphros. I see the Difference is but small ; but what is the Purport of these Holes ?

Cleon. They are intended to limit the Field of View as far as it is perfect ; and as they differ so very little from each other, it is plain, the Perfection of Vision does not depend on the Size, or Magnitudes of the Eye-glasses.—Upon the Whole, therefore, you will find, that there is but very little Preferencé to be given to the largest Microscope, on Account of the Bulk of the Frame or Glasses.

Euphros. Since this is the Case, please to let me know what are the peculiar Advantages of each Construction.

Cleon. I will : And first, with regard to the Parlour-Microscope, the Particulars which recommend it are as follow : (1.) I have observed to you before, that Grandeur pleases in every Shape, and we have naturally a high Opinion of any Thing constructed in a magnificent Taste : The Palace is preferable, for its sumptuous Appearance, to a Cottage ; though you or I could sleep, or enjoy Life equally well in either. (2.) The large Microscope is fixed on a proper Basis, and therefore Objects may be applied and viewed more readily, than when the Instrument is held in the Hand. (3.) There is in the Parlour-Microscope, generally, a much larger and more expen-

expensive Apparatus, that nothing may be wanting to render the Entertainments of this Instrument pleasurable in the highest Degree. (4.) There is in this Instrument a larger Distance between the Object-glass and the Eye-glasses, and therefore, upon the Whole, the Scope or Power of magnifying will, in some Degree, in this large Construction, exceed that of the small.—But then, on the other Hand, the small one is recommended by the following Considerations: (1.) Being of a Pocket Form, it may be carried any where, and, of Course, becomes more generally useful, than the large Microscope. (2.) The Price is considerably less; and therefore suits the Generality of People much better. (3.) The small Difference in the Effect between a large, and small Microscope, together with the above Reasons, incline many People to the Choice of the latter.

Euphras. As to the Form of the Microscopes, I presume, no great Matter depends on that; and farther, I suppose, the Two you have brought me, are of the newest Fashion and Taste. —

Gleon. They are the latest Forms in which Microscopes have been made — The three pillar'd Microscope (as it is usually called) is, indeed, an old Fashion, but then they have always been made in the large Form, and the Brass Legs, or Pillars, of a different Shape and Size from what you see in this Pocket-Microscope. — But as for the Form of this Parlour-Microscope, it is quite new, as none, that I know of, have ever been made of that Construction before; for in this Form the Microscope is placed in any Situation, either perpendicular, or parallel to the Horizon, or it may be placed in any oblique Position, as Occasion may require; besides this Advantage, there is yet another in the circular Stage that moves on a Center, and thereby shews all the different Parts of Objects in the most commodious Manner; these two Particulars, together with the Lightness, Air, and Elegance of the Form, render it, in my Opinion, most proper for a Lady's Use; to which may be added, it being contained in a neat *Shagreen* Case, with a complete Apparatus, renders it much more portable than those of the usual Forms kept in wooden Boxes.

Euphros. I think myself greatly obliged to you for the Trouble I have given you in so many Interrogatories about Microscopes, and for the Satisfaction you have given me in their Solution. At present, I think, it will be proper to desist from any farther Enquiries of this Kind, but shall be glad to embrace the next Opportunity for that Purpose.

DIALOGUE III.

On the Nature, Construction, and Use of the SOLAR MICROSCOPE.

Cleonicus.

I Have hitherto entertained you in the best Manner I am able, with an Account of microscopic Constructions of different Forms and Kinds; nor have I finished that Subject yet, as there remains one which far exceeds all the rest in its magnifying Power, or the astonishing Appearance it gives of the smallest Objects.

Euphros. This, I presume, is the Solar Microscope, which I have heard you speak of very often, on that Account—is not this the Instrument now before me on the Table?

Cleon. That is the Solar Microscope, whose Nature and Construction I shall now explain to you; and then, afterwards, entertain you with some Experiments of its Use.

Euphros. It is called the Solar Microscope, I suppose, from its being used with the Sun, or rather, that it is entirely useless without the Sun-beams; for I have heard you say, that it is applied to Use in a Room that is darkened, and then only when the Sun shines. But the Method of its Application in the *Camera Obscura*, as you call it, is a Thing as yet I have little or no Idea of, and is what, I presume, you intend to instruct me in.

Cleon. This Morning is devoted to that Purpose.—The Room is darkened and ready for Use, and the Sun will probably continue till I have dispatched, in a few Words

Words, the Description and Use of the several Parts of the Microscope.—You will therefore observe, this Instrument consists of the following Parts: (1.) A long plain Glass in a Brass Frame, which goes on the Outside of the Window to receive the Sun-beams which fall obliquely thereon. (2.) The square Plate, or Frame of Brass, is, by a Couple of Screws, fastened to a Window-shutter, containing a Hole for the Looking-glasses to pass through. (3.) In the Middle of this Plate lies a Wheel with Teeth, concealed, with a circular Rim of Brass placed over it, and is moveable by a Wheel and Pinion, which you observe in one Angle of the Plate. (4.) In the central Hole of this circular Wheel, or Piece of Brass on the Outside, towards the Looking-glass, is fixed a convex Lens, whose focal Distance is about 8 or 10 Inches. (5.) In the Hole of the same Plate, on the Face of the Instrument, is screwed the Tube or Body of the Microscope, with its Drawer or sliding Part, as you there see. (6.) On the End of this Slider is screwed a single Microscope of the first or second Form, which I have before described to you: and thus you see all the component Parts of this curious Machine as they are put together.

Euphros. Well; but, methinks, I should be glad to see the particular Use of each of these Parts, before we enter the dark Room, where I cannot so well see the Manner of their Application.

Cleon. This I can shew you just as well in a light, as in a dark Room; the Light is no Obstruction to any Thing but forming a Picture of the Object; I have provided a Board with a Hole of the same Size with that in the Window-shutter, to which I shall apply the Machine in its several Parts successively. And,

First, I put the Looking-glass through the Hole of the Board, and then screw the Plate firmly on to the same. This done, then,

Secondly, I turn the Pinion which moves the Wheel with the Looking-glass on it, towards the Sun, by which Means the Rays of the Sun are reflected from the Looking-glass, through the convex Lens into the Room; as here you see by the Experiment.

Thirdly, It is necessary in the Use of this Instrument, that the Sun-beams should be made to go strait across the

Room, or parallel to the Floor, and to fall perpendicular on the opposite Wall or Side of the Room. Now there is but one Position of the Looking-glass that will reflect the Rays in that Manner, and therefore you see here is a small Wheel, and Endless Screw, fixed on the other Part of the Plate, for moving the Looking-glass up and down, till it comes into the necessary Position; and then you observe,

Fourthly, the Beams of Light are refracted through the convex Lens to its Focus, which, you plainly see, is at the Distance of about 10 Inches from the Glass.

Fifthly, From the focal Point you observe the Rays proceed diverging, and form a large Circle of Light on the opposite Side of the Room.

Sixthly, I screw on the Tube with the small Microscope, and place the Slider therein, with the Objects intended to be magnified.

Seventhly, This done, I move the Drawer forward and backward, till I bring the Object in the Slider within a small Distance of the Focus of the convex Glass, where you may observe it is very much illuminated in the denser Part of the Cone of Rays: Then,

Eighthly, and lastly, I apply the small Magnifiers to the single Microscope, and by the adjusting Screw, move them to such a Distance from the Object, as shall shew their Image very plain and large, upon a Sheet hung on the opposite Side of the Room. And thus having shewn you how every Part is applied to Use, I shall repair, with you, to the Room made dark, there fix the Instrument, and shew you its surprising Effects.

Euphros. I shall, with great Pleasure, attend you on this Occasion, to see how Darknes itself conduces to perfect these Experiments, which depend on the strongest Light.

Cleon. Here, my *Euphrosyne*, enter the Room, and place yourself in the Chair I have there set for you; you will there be near me, to see the several Processes in the Application of the Instrument, and at a proper Distance to view the Image to the best Advantage.

Euphros. I am seated, as you direct.—You may proceed to your Operation as soon as you please.

Cleon. The first Object I shall put in the Microscope is, a transparent Scale of a Sole fish—observe its Image upon the Sheet.

Euphros. Its Image! — I see something prodigiously large, indeed; and you amaze me, when you say it is only the Scale of a Sole:—It appears at least 12 or 15 Feet long, and 6 or 8 Feet wide;—it fills almost the Side of the Room.——How thick set with long sharp Points at one End! its Substance transparent, and variegated with beautiful Undulations.——Were the whole Fish magnified in the same Proportion, it must surely be as big as a Whale.

Cleon. You might have said, my *Euphrosyne*, as big as a hundred Whales; since the Fish, magnified as much as its Scale, would appear very near half a mile long.—By this Instance, you see how Nature has provided for the Defence of the Sole-fish, since the external Part of every Scale is armed with those sharp pointed Spines, or Thorns.

Euphros. I have often observed, that the Surface of those Fish were very rough to the Hand; but never knew the Reason of it before.*—What is the next Object, *Cleonicus*?

Cleon. I have shewn you the magnified Scale of a Fish, and I will next shew the Scale of an Eel, magnified in the same Proportion.

Euphros. The Scale of an Eel, *Cleonicus*, that Expression seems to have a strange Sound: I am so great a *Virtuoso*, that I never before heard of, or knew there was any such Thing.

Cleon. That may be, and numberless others besides yourself are not only ignorant of it, but will not believe it when it is told them: Nay, the *Jews* insist that it is contrary to the *Mosaic* Law, by which they are forbidden to eat of that delicious Dish, as they apprehend that Eels come under the Denomination of that Sort of Fish which have no Scales:—But observe, on the Sheet, the Picture of one in its full Dimensions and Perfection.

* See a microscopic View of the Skin and Scales of a Sole-fish,

Euphros. A prodigious Spectacle this!—it is nearly as large as the Scale of a Sole, but of a very different Form;—its Substance seems to be one continued Piece of Net-work, proceeding in long oval Rings, as it were, from a common Center:—I observe no Bristles, or Points, in this, nor can I tell on what Part it grows on the Body.

Cleon. These Scales, my *Euphrosyne*, differ from the Scales of common Fish, in the following Particulars; *First*, they lye not on the external Surface of the Eel, but are contained under one common Covering, or Skin. *Secondly*, they do not lye one over another, as the Scales of a common Fish; but are placed one by the other, as thick as they can lye, through the whole Skin of the Eel. *Thirdly*, their reticular Form, or Net-like Texture, is such as we observe in no other Sort of common Fish-Scales; besides many other Peculiarities which I shall observe to you at another Season.—You will next behold the wonderful Appearance of a certain Species of Eels themselves, real living Animals,

Euphros. Living Animals, *Cleonicus*!—they have really so much Life and Motion, and monstrous Size withal, that I have scarce Courage enough to keep my Seat. Who could have thought to have seen, in a Moment's Time, that Sheet transformed into a Lake of Conger Eels?—They are vastly numerous, indeed, —and larger in Size than I have ever seen any Thing of the Kind; 5, 6, or 7 Feet long, and 3 or 4 Inches thick:—Their quick tortuous and serpentine Motions are really amazing and stupendous.—Pray, what are these Creatures in themselves, and how came you by them?

Cleon. These are really a Species of small Eels, or *Anguiculae*; they are found very common in sour Paste, or stale Vinegar, and some other Fluids, of which I shall have the Pleasure to entertain you, one Day or other, with the common Microscope, when you will find that, notwithstanding the Appearance they now make by the solar Microscope, they are scarcely visible to the naked Eye; such Objects of Miniature are the mighty Serpents you now see.*

* See Figure 8, in the Plate of Microscopic Animalculæ,

Euphros. They are every Way wonderful, I find.
 ———What do you intend to surprize me with next,
Cleonicus?

Cleon. You will justly admire the wonderful Mechanism in the Eye of a Fly.

Euphros. A glorious Object, indeed!—the finest Piece of Lattice-work my Eyes have ever yet beheld:—How grand and beautiful are the Works of Nature, and what great Variety in the Structure of the same Organ!—In the Surface of this small Eye, I observe Myriads of those beautiful fix-sided Figures.——Pray, *Cleonicus*, what Purpose do they serve, in this visual Organ, in the Fly?

Cleon. We are not yet acquainted with the Design of Nature in every Part of her Operation: But I shall recommend you to read the Conjectures of some of the best Naturalists upon this particular Subject, rather than give you my own Opinion concerning it*.——Every Part of a Fly is equally wonderful, as you will ere long be satisfied by the common Microscope; but they are not all equally proper Subjects for the solar Microscope: But the Wings of most Flies may be shewn to great Advantage in this Instrument, particularly those that are membranous and transparent; nay, even the hard Wings of the Scarab Kind are some of them, in the smaller Species, most excellent Objects for this Purpose—See one of them fill the whole Side of the Room.

Euphros. Is this, *Cleonicus*, the Wing of a small, contemptible Scarab?—This is a sufficient Instance, to prove how necessary it is to apply the Instruments of Art for giving us right Notions and just Ideas of the Works of Nature.——I think this is the richest, and most glorious Spectacle I ever saw, and can scarce help looking upon it as the Height of Nature's Fancy, in Point of Grandeur;—it seems all an embroidered Ground
 of

* See the magnified Head and Eyes of a Bee, in a large Copper-plate Print, with some Account of it. And in my *Optical ESSAYS* you will find a large Account of the NATURE of VISION in INSECTs explained in a Dissection of the Eye of the *Libella*, or Dragon Fly.

of Gold, embossed and studded with Diamonds, in such beautiful and regular Squares of Cheques and Compartments, as nothing but an actual View of such a high finished Piece could ever raise an Idea of.—Pray, how large may the Animal be that is thus so richly bedecked and adorned?

Cleon. This small Beetle you may have often observed crawling about upon rotten Wood, old Walls, &c. of so diminutive a Size, as not to exceed one Tenth, or Two, of an Inch, and therefore escaped your Notice: But were these minute Creatures to become magnified at once, *two thousand* Times in Length and Breadth, as is the Case of the Wing you now see, what stupendous Admiration would they excite in all Mankind!—The highest Wisdom hath directed you to contemplate the Gaiety of the Lily, and other fine Flowers of the Garden, with a Remark, at the same Time, that *Solomon*, in all his Glory, was not arrayed like one of these. But if, as I said, those Animals were to appear at large, we should find Nature much more profuse in the Richness of her Ornaments and Embellishments to them; and that the Robes they are invested with, do far surpass not only the Glory of *Solomon*, but all the Pomp and Grandeur that all the Courts in the World can afford in Works of Art.

Euphros. I should never be tired with feasting my Eyes with these delightful Scenes; but I must not detain you too long in Particulars. What is the next Object you intend shall gratify my Curiosity?

Cleon. It is what they call the *Exuviae*, or cast-off Skin of a Spider.—See the wonderful Appearance on the Sheet.

Euphros. Prodigious! nay, even shocking:—What a hideous Apparition is this! a Head three Feet long,—with 8 Eyes as big as Saucers; eight monstrous hairy Legs, as big as Mill-posts:—What Appearance must such a Spider as this make, with every Part magnified two thousand Times in Length and Breadth, as I now see it, alive and in Motion.

Cleon. Your Sex are generally intimidated enough with this Animal in its natural Size and Appearance; but were a Spider, as large as you now see this, to drop from

from the Clouds in the Middle of *Smithfield*, on a Market-day, it would scare not only the Ladies, but the Butchers themselves, and find Oxen to feed on instead of Flies.

Euphros. I don't know but that might be the Case, as I have known a Spider to have conquered an Ant, and devour it, though nearly as big as itself: But enough of this tremendous Creature. What does your Microscope next display upon the Sheet?

Cleon. A Spectacle that will fill you with equal Amazement and Delight.—See Rivulets of fluid Particles running over all the Side of the Room.

Euphros. What can this mean?——I guess, by what I have heard you say, that this is the Circulation of the Blood in animal Vessels.—But what an incredible Number of Streams there are, and with what Velocity do they flow in every Direction through the Scene!—Pray, *Cleonicus*, what Part of the Animal is it that appears thus large and transparent, and in such a wonderful Degree of Motion?

Cleon. It is the transparent Tail of a Water-Newt, which I judge to be the best Subject of all for this Purpose, and are found in every Pond of Water. The Tail of a Tad-pole will do nearly as well; as also the transparent Web and Toes in the Foot of a very small Frog; the Tail of that Fish we call the Loach; and many other Subjects may be innocently applied for this Purpose, without those cruel and inhuman Methods, practised by some who appear to have more the Form, than the Rationality of Men*.

Euphros. I abhor the Thoughts of Cruelty, in every Shape, and should rather be thought to have no Curiosity, or Taste at all, than a vicious One.—I am thoroughly sensible, by this Experiment, how the Blood flows through the Arteries to the extreme Parts, and from thence returns again by the Veins; I see the very Form and Size of the Particles of Blood: And therefore keep the Creature no longer in such a Condition, which, though
it

* The barbarous Practice of *dissecting a Frog alive*, to shew the Circulation of the Blood in the Mesentery, is here referred to.

it may give me much Pleasure, may be very uneasy to itself.—I now wait your following Exhibition.

Cleon. Keep your Eye stedfast upon the Sheet, and you will soon see a common Animal appear in quite a new Light.

Euphros. This is a terrible Appearance, indeed :—What hideous Monster do I see?—How large his Head, his jointed Horns, its bulbous Eyes, and monstrous Legs and Claws, the Motions of which are very terrible in Appearance :—I suspect, by the Form, that this frightful Creature is the Louse.—But what is that red Spot I see in the Forepart of its Body, attended with an odd Kind of Motion?

Cleon. It is a living Louse that you see, and the Spot which you mention shews the Place and Pulsation of the Heart; from which, you observe a Motion of a vital Fluid through the middle Part of the *Abdomen*, or large, hinder Part of the Body : But you see nothing like the Circulation of the Blood in other larger Animals, by distinct Arteries and Veins. How the Circulation of the Fluids are carried on in this, does not, even by this Instrument, appear*.

Euphros. Well; an uglier Thing I scarce ever saw; they are Objects of our Aversion in their natural minute State; but what an horrible Aspect they have now!—I have viewed this Monster long enough. Pray, what Appearance does a Flea make?

Cleon. I have one at Hand to shew you.—There, you see it.

Euphros. I do, sure enough :—It is as large as an Ox,—it seems to be a Creature covered with a Coat of Mail or Tortoiseshell,—its Appearance is rather uncouth than formidable, and a good deal in the Shape of a Lobster, as you formerly told me :—What an amazing Head it has, with a large black Eye.—But what is most surprising in the Structure of this Animal is, the peculiar and wonderful-Form of its Legs, by which one may easily see how Nature has prepared it for moving in the Manner it does.

* See a Print and Description of the Louse.

does.—I can likewise perceive, in the Body of this Animal, a Motion of the Fluids somewhat like that in the Loufe *.—But now for another Object, *Cleonicus*, if you please.

Cleon. I shall now entertain you with a few extraordinary Views of the vegetable Kind.—Look at the Sheet, and tell me what you think you see there, my *Euphrosyne*.

Euphros. You have suddenly transformed the Scene to somewhat like a wonderful Sort of Stars,—some of which are opaque, others transparent ;—they are perfectly round, and large as Cannon-Balls :—They are vastly numerous, and make a delightful Appearance, truly.—Pray, what can it be, of a vegetable Nature, that I see ?

Cleon. It is what the Botanists call the *Farina*, or that dusty Matter which grows on the Apices in the Middle of the Flowers, of which you see great Quantities in the Tulip, the Lily, and many others : But that which I have in the Microscope, is the *Farina* of a Holyhock, and is found in all of the Mallow Kind ; for in every Plant of a different Species, those Particles have a peculiar Size and Form, as you may observe at your Leisure in the common Microscope.—Now cast your Eye again on the Sheet, and you will see an Object that will give you Pleasure to view it.

Euphros. This is a curious Phænomenon indeed :—This has, in Truth, the Appearance of Vegetation itself :—How beautifully coloured, and regularly branched and ramified in every Part !—Pray, what do you call this, *Cleonicus* ?

Cleon. It is a Species of a very fine Sea-Plant, or Coralline, of which there are innumerable Kinds, and all make the same beautiful Appearance you now see: for not only the Earth, but the Sea is productive of Vegetables, Plants, and Trees of various Kinds and Sizes ; all which afford the most curious Objects for the Microscope.—Again, you see the Scene is changed, and another Part of a Vegetable exposed to your View.

* See a Print and Description of the Flea.

Euphros. I think the Appearance of it very fine and delicate ; but what it is, I cannot conjecture, as I never remember to have seen any Thing in a Plant of this curious Texture.

Cleon. It is a very thin transverse Slice of the Pith of Elder, and though we know so little of the Use of that Part of the Plant, yet you may be assured that something very considerable depends upon so elegant, and quite a geometrical Structure. — The next Object has a similar Appearance, but the Pores much smaller.

Euphros. Be this what it will, it is vastly beautiful ; — the Pores, it is true, are much smaller, and more numerous, and therefore a more compact Substance than the Pith ; but what Part of the Plant it can be, I am as much at a Loss to guess as I was before.

Cleon. This is a very thin Piece of Cork, which you know, is a vegetable Substance, as it is the outer Part of the Bark of a Cork-Tree ; and though we cannot so well tell the Use of these Pores in Vegetation, yet, as they render Cork a soft and yielding Substance, they make it a very fit Medium for many Uses in Life, particularly for corking of Bottles, and sundry other Uses for Fishermen, &c. — Another Object well deserves your Notice : Look upon the Sheet, and you will see it.

Euphros. I see something in Appearance very regular, full of Holes of a larger and lesser Size, and disposed in a very beautiful Order : — But this, like all other Objects in this new View, becomes quite unknown to me, however common it may be to the vulgar Sight.

Cleon. This, my *Euphrosyne*, is the essential Part of a Plant, it is a very thin Slice of Oak, cut transversely, so as to render it quite transparent ; for, by this, it appears, that the Body of a Plant consists almost entirely of long, hollow Tubes, or Vessels, the Orifices of which, when cut asunder, are what make that variegated Appearance of Ringlets of different Sizes upon the Sheet. — Those of the largest Sort are the Orifices of Air-Pipes, which is that System of Vessels which circulate the Air through the Body of a Plant ; and though some of them appear now near a Foot in Diameter, yet, in themselves, they are scarce visible to the naked Eye. — The other Order of smaller Orifices are those of the Sap-Vessels, which circulate

late the nutritious Juices of the Earth to all the Parts of the Plant; and it is these that make the very Substance of the Plant itself, and constitute those cylindric Shells of Wood which appear in cutting the Tree asunder, each of which is the Product of one Year's Growth: All which I shall more particularly discourse of, to you, at another Time.—At present, these Specimens must suffice for the Use of the solar Microscope, and for giving you a just Idea and Esteem for such an excellent Invention, and which exceed all others of the optical Kind.

Euphros. I am much obliged to you for the trouble I have given you, and for your Confinement so long in a dark Room; and I shall always look upon the Experiments of the Microscope, and especially of this Sort, as the most sublime and rational Amusements of my Life.

DIALOGUE IV.

The Description of a MICROSCOPIC APPARATUS, consisting of a Single, Compound, and Solar MICROSCOPE together.

Cleonicus.

AS the Minds of Men are affected with a Variety of different Sentiments, in regard to the Manner and Form of Things designed to answer the same Purpose, so the Artist, in order to please, is obliged to contrive his Instruments of many different Forms and Structures; for his Mechanism must always vary with the Fancies of Mankind; and nothing appears to me a greater Instance of Providence, than that Variety and Mutability which we find in the Judgment and elective Faculties of the human Mind: For if all Men were to fancy the same Thing under the same Form, and constantly to persevere in their first Choice, there would be but little Business for Men to be employed in, and the World would become a dull Scene, in Comparison of what it now is.—I have already laid before you the different Sorts of single,

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compound, and solar Microscopes, as they are usually constructed, and sold separately by themselves, for the Gratification of those who chuse to have them in that Manner:—But as some People are fond of single Structures, and like to have every Thing by itself; so others are pleased with Composition, and chuse to have as many Purposes as possibly can be answered by a Set of Instruments in the least Compass: And to oblige such Gentlemen, Opticians have found out a Method of combining the single, compound, and solar Microscope together, in such a Manner, that they are contained in much less Room, can be afforded at a less Price, and make a convenient microscopic Apparatus in one portable Case; and to give you a distinct View of the Instruments thus contrived, is proposed for the Employment of our present Hour.

Euphras. Notwithstanding you have been so kind as to furnish me with all the Instruments under the Denomination of Microscopes, yet I shall be obliged to you for a View of that more compendious Form of an Apparatus you have now mentioned, and shall gladly receive your Instructions for the Use of it.

Gleon. You see, my *Euphrasyne*, they are all contained in this Shagreen Case, and are only the essential Parts of the three different Kinds of Microscopes, to be united as Occasion requires.—Thus, the single Microscope is that which you have of the fourth Form, (Plate 44. Fig. 1.) on the upper Part of which (at L) you screw on the Body of the double Microscope, (Fig. 2.) by the lower Part of the Snout (F:) Then, when the Objects are applied in the Ivory Slider (H) on the Stage (G,) they may be viewed by any one of the six Magnifiers contained in the circular Piece of Brass (K,) as they are successively moved and placed under the central Hole in the Part (L,) since the Stage (G) may be moved nearer to, or farther from the Part (L) by Means of the Sliding-Apparatus (E F) and the two Screws (*a, b*) The Objects are illuminated by the reflecting Mirror, (M) moveable on the Joint (N,) of a Piece of Brass fixed to the Pillar (C) of the Microscope.—And thus you see how easily and readily you form a compound Microscope at Pleasure.

Euphros. It is with great Satisfaction that I observe it, and which I shall frequently put in Practice; but, pray, *Cleonicus*, could not the magnifying Glasses be applied in a Slider, as they are in the second Form of single Microscopes? (Plate XLIII)

Cleon. Undoubtedly, they may:——But each Way is so easy and convenient, that it is hard to say which is best: But, as you have the sliding Glasses already in the Microscope of the 2d Form, I have chose to give them you in the circular Plate in this.

Euphros. Very good, *Cleonicus*; but how do you proceed to apply this single Microscope to the Composition of a solar Microscope?

Cleon. This is done with a great deal of Ease; for you have only to observe, that on the external Part (A) of the Drawer (B) in the Tube (C) of the solar Microscope, there is a Screw; and also in the Foot (A B) of the single Microscope there is a central Hole (O,) with the Threads of a Screw cut in it, the same with those on the Part (A) in the solar Microscope, and consequently the Drawer (A) may be readily screwed into the Hole (O,) and thus the solar Microscope is completed.

Euphros. I readily perceive it is; for, when the Plate (G F) is fastened upon the Window-shut, the Disposition of the single Microscope is horizontal; and when the Speculum (M) is turned down upon the Pillar (C,) then the Rays of Light reflected from the Looking-glass (H) without the Convex Lens at (D) they will, by its Refraction, be converged in such a Manner upon the Objects in the Slider (H) as to illuminate them very strongly, so that their Images, formed by the Glasses in the Plate (K,) may be sufficiently visible in their various Degrees of Magnitude on the opposite Side of the Room.—This is, indeed, a very simple, and, at the same Time, a very artful and elegant Composition of optical Instruments. Pray, can any Thing further be expected to assist us in viewing the *Minutiae* of Nature, besides the Instruments you have now described?

Cleon. I am greatly pleased to find you inquisitive; many People of a less happy Disposition would have thought I had harangued them full long enough on this Subject:——But, as I have often told you, I am

determined that nothing shall escape your Notice which is deserving of it, and is, at the same Time, in my Power to lay before you; and therefore I shall hereafter supply you with other Ways and Means for viewing small Objects:———I mean, by those Instruments we may properly call catoptric Microscopes, or such where the Vision of Objects is effected by reflected Light; and you must know, and I doubt not but you will then find, by Experience, that this is the most exquisite and perfect Kind of Vision that Nature affords: For all the Microscopes that we have hitherto been contemplating the Nature of, consist of Lenses only, and produce their Effects by refracted Light; therefore the Vision of an Object will be imperfect upon two Accounts; the first is, because the regular Refraction of Rays will be obstructed by the Figure of the Glass; because the Rays which go through one Part of the Glass are not refracted precisely to the same Point with those which pass through another Part; and therefore every individual Point in the Object cannot be represented by a single Point in the Image, but will be, as it were, dilated into a small Space, and, consequently, the several Points of the Object will be confusedly blended together in the Image; therefore it must not be viewed by a Glass that magnifies too much, lest it should discover the Imperfection of the Image, and render the View disagreeable.

Euphros. You are now upon such a nice Subject, and what I have been so little used to think of, that I can but just comprehend your Meaning.—I think, you intend I should understand, that unless every Point of the Object, which sends forth Rays to the Glass, could have all those Rays collected into a single Point, the Vision or Image of that Point cannot be distinct and perfect.—Am I right, *Cleonicus*?

Cleon. It is the very Idea I endeavoured to convey; but that is not to be absolutely effected by Glasses.—— Besides this, there is another, and still greater Cause of imperfect Vision by refracted Light, and that is, the different Refrangibility of the Rays of common Light, that is to say, the Rays of Light, proceeding from the same Point of an Object to the same Part of the Lens, will some of them be refracted to one Point in the Axis, and

ANGLE, COMPOUND, and SOLAR MICROSCOPES.

Fig 1.

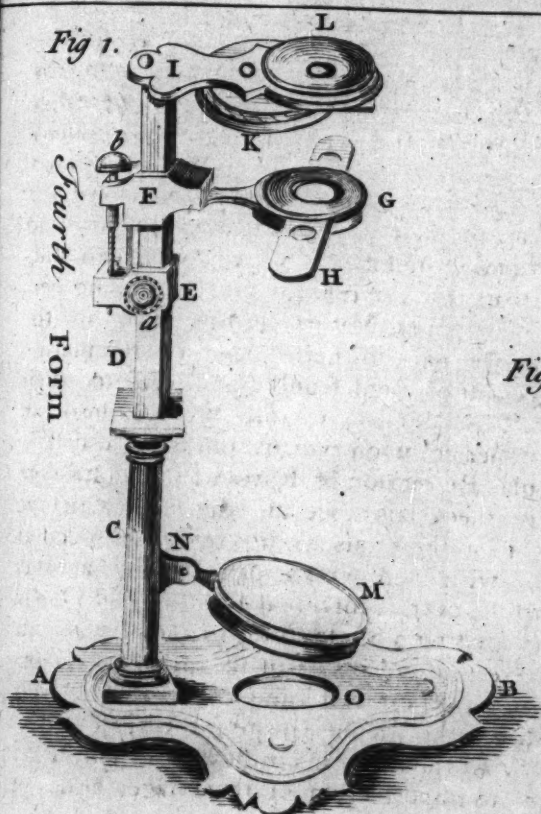


Plate XLIV.

Fig 2.

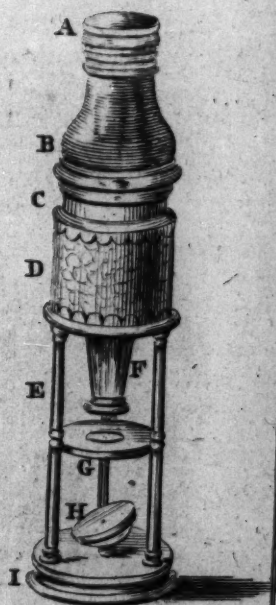
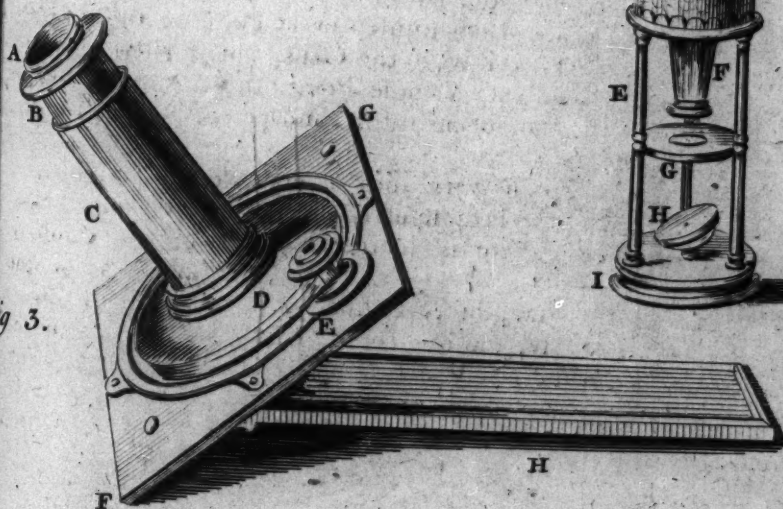


Fig 3.



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and some to another: Or, in other Words, some will be more, and others less refracted, and, consequently, the several Points of the Object will be very much dilated and confused, in the same Manner as I said before was occasioned by the Figure of the Glass; but in a much higher Degree:——Nor is this the only Misfortune of refracted Vision arising from the Rays being differently refrangible; for each particular Sort of Rays that are contained in a Beam of common Light, will, at the same Time, act differently upon the optic Nerve, and produce different Ideas of Colour, according to its different Degree of Refrangibility; and therefore one and the same Point of an Object is not only, by Refraction, multiplied, as it were, into many Points; but is likewise diversely coloured in each of those Points in the Image, and, consequently, when the Image of any Object, formed by those Glasses, are viewed by a very deep Magnifier, they will appear not only very indistinct and distorted, but variously coloured at the same Time.——Upon all which Accounts it is easy to observe, that we can arrive at greater Powers of magnifying small Objects by single Microscopes, than by compound Ones; because, in the former, we view the Object itself, and in the latter its imperfect Image:——But as one of those Causes of the Imperfection of Vision is much less by reflected Light, and the other wholly avoided, it will, from thence, appear how much preferable a *Catoptric Microscope* is to a *Dioptric* One.——But, that you may be apprized more thoroughly of this important Subject, which is the Foundation of the Theory, or Doctrine of Colours; I must take another Opportunity of instructing you therein, by such Experiments as I make no doubt will afford you a very agreeable Entertainment, as well as give you a more accurate Insight into the Nature of Vision, and the Perfection of optical Instruments; especially that Part we call Telescopes, the Nature of which cannot be well understood without it.

DIALOGUE V.

Of the COLOURS of natural BODIES, and of the RAIN-BOWS, illustrated by Experiments of the PRISM, &c.

Euphrosyne.

WHEN we last conversed together, you raised my Expectation in regard to the Theory of Colours. I think, you then told me, that the different Refrangibility of Rays was the Cause of Colours in all the various Objects we view; and that the Proof of this was easy for me to understand, by Experiments: If this be so, *Cleonicus*, nothing will equal the Pleasure and Happiness which the present Hour will afford me.

Cleon. You will find every Thing I have said, relative to this Subject, to be true.—As the Pride, Gaiety, and Beauty of Nature appears more in the rich Variety of Colours, than in any one Thing besides, and seem as if intended in a particular Manner to pleasure and adorn your Sex; I know of nothing that can prove more *a propos* for a Lady's Study than the beautiful Doctrine of the Colours of Light, and which is more easily attainable by Experiments of the Prism.

Euphros. I have partly experienced already the Truth of what you now say.—You remember very well, when we were Children, how often we diverted ourselves with the beautiful Colours that we observed in the Prism that my Father had in his Study, and how often we delighted ourselves with viewing the exquisite Circles of coloured Light, which we always observed in those thin Bubbles which we blowed up out of Soap-water with the Shaft of a Tobacco-pipe.—I little thought then that these were Subjects of so curious and philosophical a Nature, as I now find they are.—The wonderful Colours of the celestial Bow, in like Manner, strike every one's Eye; but the Phænomena of Colours, beautiful as they are, are more generally the Subject of *Sense*, than of the *Understanding*.

Cleon. All the World, as well as you, might have said this before Sir *Isaac Newton's* Time; they all admired the Variety of natural Tints and Colours, but never understood the Reason of it; though many of the Philosophers attempted to discover the Cause of Colours, and particularly to account for the Rain-bow, no one was so happy as to succeed in that Enquiry, before Sir *Isaac*; his great Sagacity in reasoning about natural Things, after he had observed the Effects of the Prism, and found that a Beam of Light was variously refracted through it, concluded, that this different Refrangibility of Rays was certainly the Natural Cause of Colours, as I observed to you at our last Interview.

Euphros. In what Manner did he proceed to confirm this Discovery?

Cleon. I will shew you some of his Experiments, in the darkened Room, with the Prism, and then you will be better able to judge of this Matter.—For this Purpose, you have nothing to do but to close the Window-shutters, admitting only a Beam of Light through the Hole, as the Sun now shines very favourably for that Purpose, and I have here an Apparatus to place the Prism properly in that Beam of Light.

Euphros. The Windows are closed, as you directed, and the Beam of Light darts through the Hole to a great Distance on the Floor.——Where is now your Prism, *Cleonicus*?

Cleon. I placed it in its proper Frame on the Table, to receive the Beam of Light,—and now you observe how beautifully that Beam is refracted into all its particular, and differently coloured Rays.

Euphros. A very fine and wonderful Spectacle, indeed!—I see the cylindric Beam of solar Light pass into the Prism:—From thence, I observe it proceed dilated and variously coloured to the other Side of the Room, in Rays which paint an amazing Spectrum of Colours.

Cleon. This is the coloured Image of the Sun, by Refraction, thrown into that oblong Form:—But it requires to be better defined; that you may view it more distinctly, and to give you a better Idea thereof, I shall make the Rays pass through a Lens, applied to the Hole of the Window-shutter, and from thence, falling on a Look-

ing-glass properly inclined on the Table, shall depict the Sun's Image on the opposite Side of the Wall.

Euphros. I see it; and an accurate beautiful Circle it is.

Cleon. I shall now remove the Looking-glass, and place the Prism in its Stead, and you see the circular Spot no longer continues, but is now transformed, by Refraction, into the party-coloured Spectrum, and is now truly and nicely defined in the Focus of the Lens.—— This Spectrum is still of the same Breadth with the Sun's circular Image;—it is only dilated in Length, and is circular at Top and at Bottom.

Euphros. Those Particulars evidently appear,—I have been endeavouring to count the Number of different Colours, and think I can count five pretty distinctly;—for all the lower Part appears of a Red, gradually declining into a Yellow,—to the Yellow succeeds an intense Green,—above that a bright and lovely Blue, and, on the upper Part of all, a soft, but glorious Mazarine, or violet Colour.——I never saw Colours in such Perfection before.

Cleon. The Reason is, because you never see them in so simple a State as now; for the Rays of Light are generally blended, more or less, by Refraction and Reflection from natural Bodies, and therefore produce Colours less bright, less distinct and perfect, than what you now behold.——Sir *Isaac*, in his more accurate Experiments, could plainly discover seven different Sorts of Colours, viz. red, orange, yellow, green, blue, indigo, and violet, and that each Colour gradually degenerated into the succeeding.——The Spaces which these Colours severally occupied in the Image were nearly equal to the Intervals of a Monochord, when divided so as to sound the seven natural Notes of Music;—and as there were plainly seven different Colours of Light, so he reckoned seven different Degrees in the Refrangibility of Rays.

Euphros. But what would be the Consequence of receiving any Part of this coloured Light by another Prism? Should we not observe that Light to be again differently refracted, and producing a new, and different Order of Colours, from what we now see by the first Refraction?

Cleon. One might imagine that it would be so, but we find the contrary by Experiment;—for by a Lens of a shorter Focus, together with a Prism, I will shew you the coloured Image, on a Screen, placed in the Middle of the Room, sufficiently large to receive the Whole; and in the Screen there is a round Hole, through which the Rays of any Colour may pass, by removing the Screen up and down upon the Stand.——Thus, for Instance, I place the Hole against the blue-coloured Part of the Image, so that none but the blue Rays go through it,—and then you observe, on the opposite Side of the Room, those blue Rays, after they pass the Prism, make only a blue Image,—that they are refracted, is true, from the Direction of the incident Rays; but they are not dilated, or separated into different Sorts, as by the first Prism the common Beam of Light was:—The same will be the Case when I move the Hole of the Screen to the yellow Rays;—for now, you see those Rays, falling on the second Prism, are refracted to the Side of the Room, and there make a yellow Spot only, of nearly a circular Form.——And this I might shew of all the rest.

Euphros. These Experiments seem to be curious, and exquisitely decisive: I plainly learn from hence, that the Rays of the Sun's Light are the Grounds, or natural Cause of Colours, and that they are very differently refrangible.——But how comes it to pass, *Cleonicus*, that we see Bodies variously coloured in Consequence of this? By looking in a Prism, we see all Bodies variously coloured; but in Glasses, or transparent Bodies of other Forms, we see them in their own proper Colours only.

Cleon. The Reason of this is founded in a Physico-mathematical Theory of Refraction, * resulting from the two
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* Which see in our Institutions of *Dioptrics*.——And, for farther Illustration of this Subject, we have added a Copper-plate Print (*viz* Plate XLV) in which the Experiments above mentioned are severally represented, by Beams of Light entering the dark Room thro' optic Glasses, and refracted thro' Prisms, in the Manner as there described; so that, we apprehend, nothing farther is necessary for Explanation, but bare Inspection.

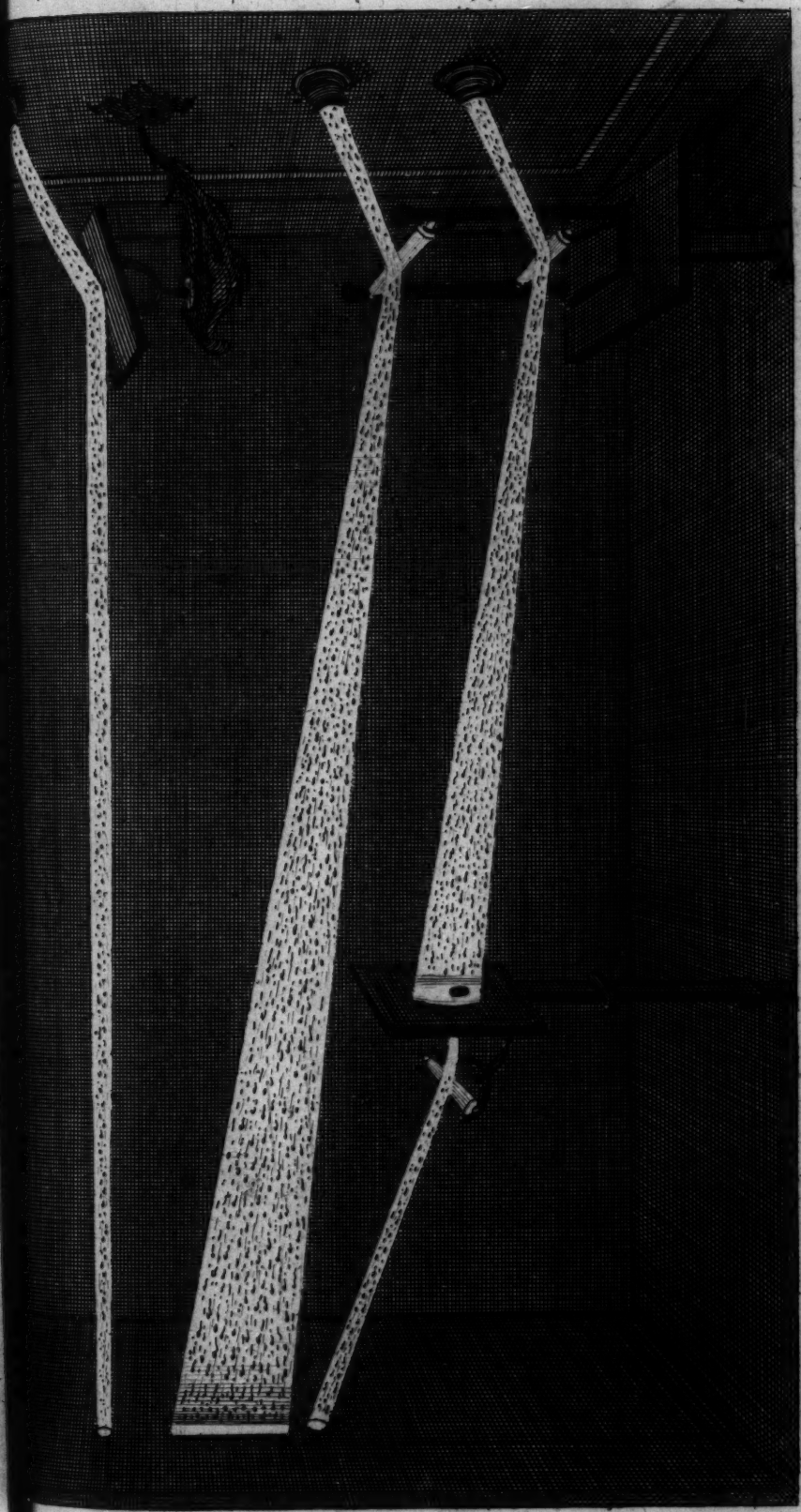
Sides of a Prism being inclined to each other; but in any other transparent Body, whose Sides are parallel, or nearly so, whatever Alteration was made by Refraction at the first Surface, is reversed by the second, and consequently, the refracted Rays are in the same State with the incident ones, and, therefore, make no Alteration in the Appearance of Bodies in any respect.—But here we must except the Figure of a Globe; for the two opposite Sides of a Globe must be considered, not as parallel, but inclined, and therefore will produce a Refraction of Rays in the very same Manner with the Prism. If Rays of Light fall on the Surface of a Glass Sphere filled with Water, they will be refracted to the other Side, and there shew a coloured Spot of refracted Light; from this Part the Rays will be reflected to another Part of the lower Surface, and there be refracted a second Time into the Air, and dilated into all the different coloured Rays; so that if a Person's Eye was placed under such a Globe, to receive the Rays after a second Refraction, he would observe all the different Colours appear in that Globe.

Euphros. I should be glad, methink, if not too much Trouble, *Cleonicus*, to see this illustrated by Experiment; for bare Description conveys not so clear an Idea.

Cleon. I was fully aware of that, and therefore have provided, for you, a Globe filled with Water, and which I shall suspend in a Sun-beam, at such a Height that you may easily observe the Phænomenon that I mention.—See, there it hangs;—and receiving the Light on the upper Part, refracts it from the lower into all its different coloured Rays, and thereby making a Circle of coloured Light on the Floor, very much resembling the Rain-bow.

Euphros. There are, indeed, all the Colours of the Bow; and a glorious Phænomenon it is.

Cleon. It will now be easy for you to observe, that if you place yourself in such a Manner, respecting the Globe, that the Rays of Light of different Colours may successively fall upon the Eye, then those different Colours will all appear in the Globe, which before made the variegated Arch upon the Floor.



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Euphros. I will place myself as you direct——And now, as I move my Eye, I see the several Colours succeed each other in the same Part of the Globe, agreeably to what you have said.——I suppose it is from hence that you are able to explain the several Colours of the Rain-bow.

Cleon. By this Experiment you understand the Reason of that Part of the *Iris*, or Bow, which contains the Circle of strongest Colours, and which we emphatically call the *Rain-bow*; for if this Globe of Water was placed aloft in the Heavens, it is very evident that the Sunbeams would be there refracted thro' it, as they are here; and then, suppose your Back was turned to the Sun, as it now is, then your Eye, remaining fixed, would perceive only one Colour, suppose that to be the first or red coloured Ray;——then, since the Orange is refracted a little above the Eye, if the Globe was to descend through a little Space it would cause that orange Ray to fall upon the Eye;——by descending a little lower, the yellow Ray comes upon the Eye;——and supposing the Globe to continue descending, the Green, and Blue, the Indico, and Violet, will successively pass over the Eye, and consequently you will observe, in the different Parts of the Heavens through which the Globe descends, the different Colours of its several refracted Rays respectively;——and therefore, since in a Cloud, on which the Sun can shine, the Globules of Water will each of them refract the Light in the same Manner this larger Globe does, and consequently some of those Globules will be in that Position that will cause the red Rays to fall upon the Eye,——others, next to them below, will send forth orange coloured Rays to the Eye;——the Drops next to them will cast a yellow Ray to the Eye,——and those successively in order below them will refract the blue, indico, and violet coloured Rays to the Eye;——and thus, in a certain Space in the Cloud, all the Colours will appear;——and since, under the same Angle, the same Phænomena will be produced, therefore a Circle of this various coloured Light must necessarily be produced in the Cloud.

Euphros. I think, I pretty clearly apprehend you, for the *Rationale* of the brightest Bow; but there is one which
we

we commonly call the *Water-Gall*, which is a fainter Circle of Colours in a superior Situation to the other.—Can you give me any Idea, *Cleonicus*, how this comes to pass?

Cleon. I will endeavour at it, my *Euphrosyne*.—In order to this, you must understand, that the Rays of the Sun in this Case fall upon the Globe in the lower Part, from whence they are refracted to a Part behind in the lower Hemisphere;—from thence, after two Reflections, they are thrown to the fore Part of the Globe, at some Distance above the incident Rays;—lastly, from this Part they are refracted out of the Globe in all their different coloured Species to the Eye:—and this I shall shew you by Experiment; for now I will direct the Beam to the lower Part of the Globe;—then you see plainly the coloured Spot behind, to which it is refracted, then casting your Eye on the upper Part you see the Point to which the Beam is reflected;—from whence it is a second Time reflected to the fore Part of the Globe;—and from thence, you see it a second Time refracted out of the Globe into the Air, and the Beam thereby dissipated into all its different coloured Rays:—And now you plainly see, by the Colours on the Floor, as well as from the Reason of the Thing, that the several Rays in the Beam lie in a different Order from what they did when refracted from the Globe before; for there the upper Part was violet and the under Part red; whereas, in the present Case you observe the red Rays are the upper Part of the Beam, and those of the violet Colour in the lowest Part.—Therefore, the two Bows in the Heavens must necessarily appear with their Colours inverted;—and, lastly, you will understand, that as in the present Case there are two Reflections of Light in the Drop, and in the former Case but one Reflection, and that a considerable Quantity of Light is lost at each Reflection, therefore the refracted Beam will have less Light, and the Colours, of course, will be more dilute and faint, which you always observe to be the Case of the superior Bow.

Euphros. I can partly see, from all that you have said, the general Reason of both the Bows;—and I could almost wish, that instead of so fine a Day, it had happened to have

have been a stormy, or a rainy one, that I might have seen the Bows just now in the Heavens, while the Thing is fresh in my Mind.——This Lecture is most proper in the Spring Season, when *April* Showers so frequently present us with this Experiment, at large, in the fable Clouds.

Cleon. You still have your Wish, my *Euphrosyne*, in every Sun-shiny Day.——For here you see a beautiful Instrument, which is called an *artificial FOUNTAIN*, with a various Apparatus for making different Kinds of *Jet d'Eaux*; amongst which, one is particularly designed to throw up many fine Streams of Water to a great Height, which, as they spread very wide, mix and blend together in their upper Part, and form a beautiful Shower of artificial Rain; and, therefore, when I set this Fountain in the Sun, and let it play, if you put yourself in a proper Position, you will see, in the descending Drops of the Shower, the same Appearance of refracted Light, and, consequently, the two Bows formed in the same Manner as in a natural Shower.

Euphros. Such an Experiment will give me great Entertainment; but you must tell me in what Situation I must put myself, in order to view it.

Cleon. This you will know by only considering, that the Rays go into, and come out of the Drop on that Part of it which is next the Sun; and therefore, that the immersing Rays may fall upon your Eye, your Face must be directed to the Shower, and, consequently, your Back to the Sun.——Therefore, when you see the Fountain playing, you move one Way or other, 'till your Shadow points directly to it, and then you will observe the curious Appearance of the Bows.——See, now the Fountain plays.

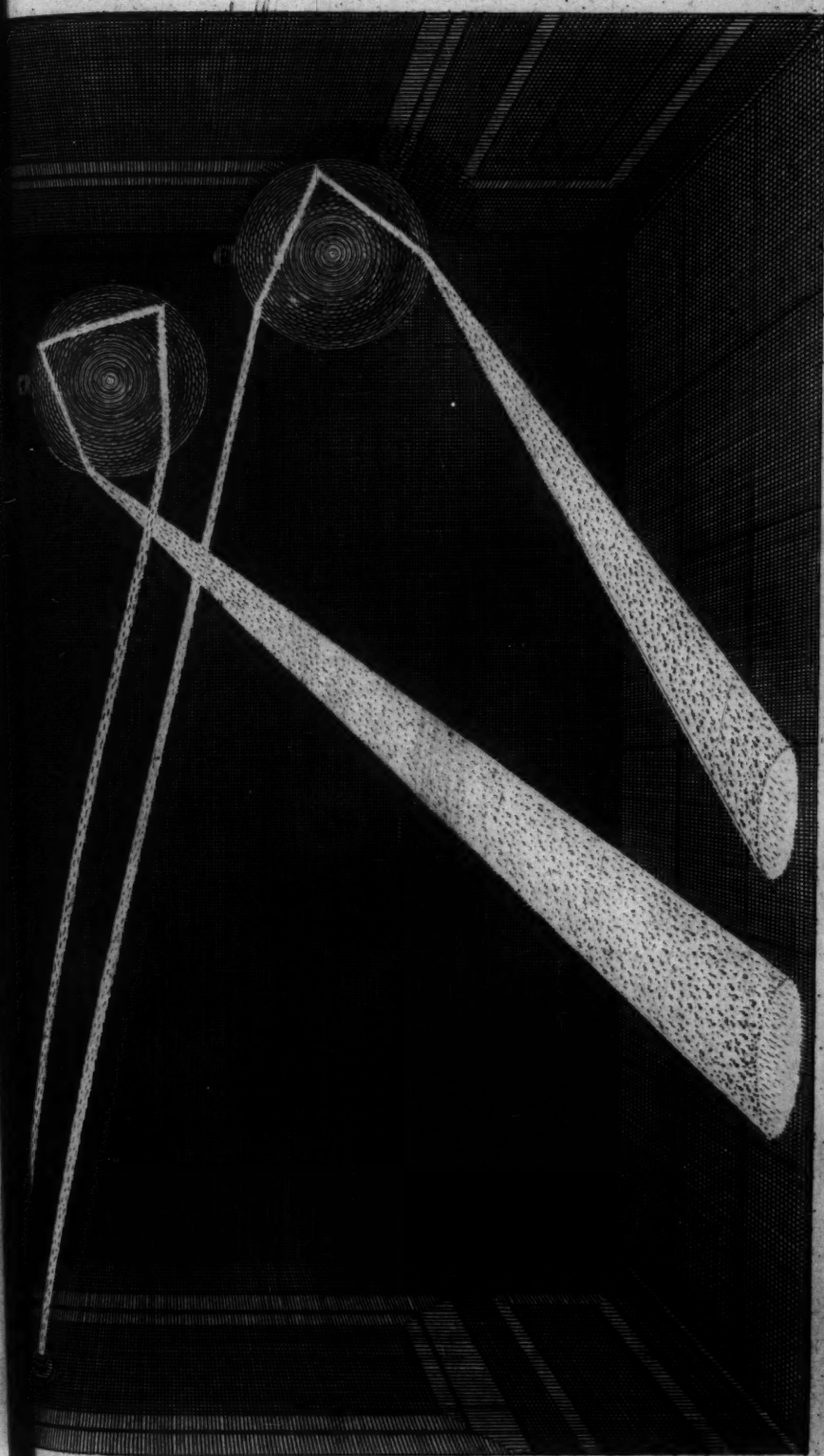
Euphros. It makes a natural, and large Shower, indeed.——My Shadow directs me to the proper Position:——And now I truly see all that I could wish for——The Colours of the Rainbow, very strong and vivid—those of the Water-gall, languid and faint—The Colours of each in an inverted Order.——But what surprizes me most of all, *Cleonicus*, is that when I know this artificial Shower is so near me, the Bows appear, notwithstanding that, as far off, and as large as those that we really see in the natural Showers of Rain.

Cleon. The Reason of this is, because the Sky is the apparent Place of all Things that we observe in the Air; there the Moon appears as well as the Stars, and there the *Halo* appears about the Moon, though formed in the thick Fog of the Atmosphere, near the Eye.—By the Laws of Optics these Things must be so; and you see the two Bows, that are not above 30 Feet from you, and, in themselves, very small, extend to vast Dimensions, and Distance in the Heavens.

Euphros. I don't know that I ever saw an Experiment which afforded me greater Pleasure, and, in its own Nature, so curious and sublime.—What a wonderful Scenery of Nature is here displayed! Surely the Doctrine of Colours is highly worthy of every Person's Contemplation.

Cleon. And yet, when we consider that though those various Beauties of Nature are the common Objects of Vision, how few there are that understand the Reason of them, and how much fewer still are any Ways anxious about it; it must appear a wonderful Thing to every rational Man.—Not only the Ladies, but Gentlemen love to see themselves rendered conspicuous by Garments and Habits of different Colours and Dyes; but if those Colours are deemed so great an Ornament to the Person, how much more will the Knowledge of the natural Causes of them adorn and become the reasonable Mind.—If this be neglected, the *Peacock* has a much better Claim to Pride, from the Decorations of Nature, than any of the human Species, whose Colours are, at best, but mixt and imperfect, when compared with the genuine and simple Colours, intensely heightened in the Plumage of that stately Bird.

Euphros. I must confess, though I have no Aversion to moderate Gaiety and Dress, yet the *Rationale* of the Colours I wear give me a Satisfaction and Pleasure of a much higher Kind; for now, I not only put on a *red*, a *yellow*, or *blue Ribbon*, but they give me Occasion, at the same Time, to reflect on the Reason why they are such, and thereby double my Pleasure in the Use of them.—For I observed, while you were shewing me the Experiments of the Prism in the dark Room, that whatever Object was placed in the refracted Beam of coloured



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Light, appeared constantly of the Colour of those Rays that fell upon it, 'because those Rays were alone reflected to the Eye; and, therefore, in regard to any Colours in Objects by Reflection or Refraction, I am taught, by these Experiments, to understand, that they proceed only from such or such particular Sort of Rays, as are reflected or refracted to the Eye.

Cleon. You apprehend this Affair very happily; the Thing you mention comprehends near the whole *Rationale* of the Doctrine of Colours ——— When Objects reflect or refract the Rays singly, they must necessarily appear of the Colour proper to those Rays; ——— but some Sorts of Matter will reflect one Sort of Rays and refract another; and therefore appear of one Colour by Reflection, and another by Refraction; thus, for Instance, Leaf-gold reflects the yellow-making Rays, and therefore YELLOW is its common Colour, but it transmits the green and the blue Rays, and therefore appears of an *azure Colour*, by refracted Light. ——— Such Bodies as throw up all the Rays promiscuously must appear *white*, which is the natural Colour of the Sun's *Light*, where all the different coloured Rays are uniformly blended together: ——— On the other Hand, such Bodies as im-bibe all the Light, and reflect little or none, appear of a dark, or black Colour, if I may so speak, for in Strictness of Speech, Blackness is the Absence of all Colour, rather than a Colour itself. ——— Lastly, as two or more different coloured Rays are reflected and refracted from Bodies they will exhibit a compound or motley Colour, and thus all Variety of Colours in Bodies may be readily accounted for by the different Refrangibility and Reflexibility of Light. ——— But I must recommend to your Perusal some easy Treatise on this Subject, which will farther enlarge your Ideas and Notion of the Doctrine of Light and Colours; the principal of which is Sir *Iaac Newton's* Treatise of OPTICS. *

* The Reader may also please to peruse our *Institutions* of DIOPTRICS, especially the popular Part; also Chap. VII. on the Subject of prismatic Colours, p. 140. — And farther, for Illuf-

Euphros. Well; I have pretty well tired you for this Time; I shall peruse that great Author's Book, and shall not be a little proud if there be any Thing in his Writings that I can pretend to understand.—Pray, *Cleonicus*, what is to be the Subject of our next philosophical Conference?

Cleon. By the present Experiments and Discourse, I have endeavoured to prepare you for understanding the Doctrine and *Rationale* of Telescopes, the different Forms, Construction, and Uses of which I shall discourse of to you as Opportunity will permit, and which, I make no Doubt, will prove Subjects of agreable Entertainment.

DIALOGUE VI.

On the Original of TELESCOPES; and their general NATURE, KINDS, and USES explained.

Euphrosyne.

WELL, *Cleonicus*, here is an illustrious Appearance of various Kinds of Instruments, most certainly; pray, are they all of that Kind you call Telescopes?

Cleon. They are, my *Euphrosyne*, but of different Sorts and Forms.

Euphros. Pray, what is properly imported by the Word Telescope? for I observe it is a general Name for Instruments of many different Sorts.

Cleon. The Word Telescope is of *Greek* Original, and signifies an Instrument intended to *perfect* the Sight, that is to say, to improve and perfect the Sight of any Object, which

Illustration of the foregoing Doctrine of the Rain-bow, we have added a Copper-plate (Numb. XLVI) to render visible to the Eye the Manner in which the Beam of Light enters the Drop, is reflected in it, and refracted from it, in the Two Experiments for shewing the Colours of each Bow, respectively; and which, we suppose, can need no other Explanation than bare Inspection.

which the Eye alone is not fitted to discern; these I have observed to be such as are exceeding small, and others which are very remote; for the Limits of natural Vision, are, on one Hand, the Distance of about six or seven Inches from the Eye; and, on the other, an Angle of about one Minute of a Degree; unless distant Objects are seen under an Angle greater than that, they cannot be distinctly viewed by the Eye; and though the Word *Telescope* is general, and comprehends all Glasses that tend to improve Vision, yet Custom has restrained it to mean that particular Sort only, which relates to distant Objects; so that, by a TELESCOPE is usually signified an Instrument that perfects the View of distant Objects.

Euphros. Is the Invention of Telescopes of ancient or modern Date?

Cleon. It is certain that it is not of very ancient Date; the famous *Roger Bacon*, before the Year 1300, was the first that we find making any particular Mention of Instruments for magnifying small Objects, or making very remote Objects appear plainly to the View; and it is worth while for you to be acquainted with some of his Expressions, to this Purpose, which are as follow:—*for thus Lenses and Speculums may be figured, that one Object may be multiplied into many,—that those which are posited at a great Distance, may be made to appear very near;—that those which are small may be made to appear very large, and those which are obscure to appear very plain;—and we can make Stars to appear where we will*—One would think, from such kind of Expressions as these, and other Tracts which he wrote upon the Subject of Vision, that this Author must have been well acquainted with the Nature, Construction, and Use of Telescopes, and all the Glasses which compose them. But our modern Critics in Optics deny him not only the Invention, but even the Knowledge of any such Construction as we at present call Telescopes.

Euphros. I cannot say but I should at once have concluded that *Roger Bacon*, by his Manner of speaking, had been an excellent Optician; but if he was not, can you tell me, *Cleonicus*, who was the Author of so useful an Invention?

Cleon. I do not wonder to find you so very particular in enquiring after the Inventor of so excellent an Instrument.——The great HUGENIUS says, *That in his Opinion, the Wit and Industry of Man has not produced any Thing so noble, and so worthy of his Faculties as this Sort of Knowledge, (viz. of the Telescope); insomuch, that if any particular Person had been so diligent and sagacious as to invent this Instrument from the Principles of Nature and Geometry, for my Part, I should have thought his Abilities were more than human; but the Case is so far from this, that the most learned Men have not yet been able sufficiently to explain the Reason of the Effects of this casual Invention.*——This Author farther adds, that though the Invention of this Instrument was certainly casual, yet *James Maetius, a Dutchman*, is supposed to be the first Inventor; but, said he, to my certain Knowledge, Telescopes were made before his Time, viz. about the Year 1609, at *Middleburg, in Zealand*, either by * *John Lipperheim*, or *Zachary Jansen*; notwithstanding this, it is certain, that *Baptista Porta*, in his Book of natural Magic, several Years before, had delivered some Sketches of the Art of making Telescopes; but what he had done in that Way was merely accidental, and not the Effect of any Skill in Dioptrics.——After the Fame of the *Dutch Telescopes* began to spread abroad, it soon reached the Ear of the famous *Galileo*, who being a considerable Mathematician, set about improving the rude Forms of the first Inventors, and soon made them in that Perfection that he, the first of Men, discovered the *SATELLITES of JUPITER* by one of his own making, and after that Time they became common, and soon made their Way into every Corner of the learned World.

Euphras. By the Accounts you have now given, whoever might, at first, casually hit upon the Construction of what you call Telescopes, yet it appears, that *Galileo* was the first who improved it into any of the Forms now in use. Pray, have you any Telescopes, of the original Construction, by this famous *Italian*?

* There are two elegant Prints of these two Inventors of the Telescope, from the Paintings of *BERCKMAN*, in which their Names are *ZACHARIAS JANSEN*, and *HANS LIPPERHEY*.

Cleon. We have one of the Form he first contrived, and it is the most simple, as well as the most distinct of all others,—and, to this Day, is called *Galileo's Telescope*; of which I shall, by and by, give you a more particular Account of its several Parts:—But as this is such an interesting and curious Point, I cannot but think you will be pleased, if I give you an Account, in his own Words, of his Improvement of this Invention, which he published in his Book entitled, *Nuncius Sidereus*, in *March, 1710*, as follows:—“Near ten Months ago it was reported, that a certain *Dutchman* had made a Perspective, through which many distant Objects appeared distinct as if they were near; several Experiments were reported of this wonderful Effect, which some believed, and others denied; but having had it confirmed to me a few Days after, by a Letter from the noble *James Badovere*, at *Paris*, I applied myself to consider the Reason of it, and by what Means I might contrive a like Instrument, which I attained to, soon after, by the Doctrine of Refractions: and, first, I prepared a leaden Tube, in whose Extremities I fitted two Spectacle-glasses, both of them plain on one Side, and on the other Side one of them spherically convex, and the other concave. Then, applying my Eye to the concave, I saw Objects appear pretty large, and pretty near me; they appeared three Times nearer, and nine Times larger, in Surface, than to the naked Eye: And soon after, I made another which represented Objects above sixty Times larger; and, at last, having spared no Labour nor Expence, I made an Instrument so excellent as to shew Things almost a thousand Times larger, and above thirty Times nearer, than to the naked Eye.”——And in another Part of his Writings he tells us, that——“He was at *Venice* when he heard of the Effects of Prince *Maurice's* Instrument, but nothing of its Construction; that the first Night after he returned to *Padua* he solved the Problem, and made his Instrument the next Day; and, soon after, presented it to the Doge at *Venice*, who, to do him Honour for his grand Invention, gave him the ducal Letters, which settled him, for Life, in his Lectureship at *Padua*, and doubled his Salary, which then became treble of what any of his Predecessors had enjoyed before.”

Euphras. I do not wonder to find that this celebrated Man met with such Honours and Preferments, from that great Patron of Learning, for his perfecting and reducing to Practice so excellent a Discovery:—But I long to be informed of the Nature and Structure of his Telescope.

Cleon. It will be necessary to begin with that; since, as I informed you before, it is the most simple Structure of this Kind of Instruments——But, that you may be apprized of the *Rationale* of a Telescope in general, it must be considered, that the Design of such an Instrument is to enlarge the optic Angle, under which distant Objects appear; so that by that Means they might be rendered more perfectly visible, or distinct to the Eye.—This is done by forming the Image of a distant Object in the Focus of an optic Glass,——and then by viewing that Image by another single Glass, or Lens, of a short focal Distance.

Euphras. You will be a little more particular in explaining this Matter, before I can readily apprehend you.

Cleon. I intend so to be; for neither you, nor any one can be supposed to understand the Effect of a Telescope in a Word or two:——Therefore, you will recollect that in the Focus of any convex Lens (from the Experiments I formerly shewed you) the Image of every Object is formed——and that that Image subtends the same Angle at the Center of the Glass, as the Object itself does; that is to say, in other Words, the Object and its Image are both seen under the same, or equal Angles, by the Eye placed at the Center of the Glass.—In the next Place, you are to observe, that as the Image of an Object is in every respect an exact Picture, or Representative of that Object, it will follow, that the same Idea is formed in the Mind, of the Nature, Form, Magnitude, Colour, &c. of the Object; whether the Eye at the Center of the Glass views the Object itself, or the Image thereof in its Focus.——Farther, you will remember, that any Object, placed in the Focus of a Glass, will appear very distinctly through it, as the Rays proceeding from the Object to the Glass are, by Refraction through it, rendered parallel to the Eye, which is a necessary Condition for distinct Vision.——Therefore, if an optic Lens of

the convex Form, and of a short focal Distance, he applied to view the Image before mentioned, you will easily understand, that then that Image will appear distinctly; and, consequently, the Object itself will be thereby shewn distinct in all its Parts; and so much the more so, as the Differences between the focal Distance of the two Lenses is greater, within a *limited Degree*.—— And therefore, lastly, as the same Image is nearer to one Lens than the other, it will of Course subtend a larger Angle at the nearest Lens, and therefore will, through it, be seen larger than through the other; and consequently the Image, and, of Course, the Object will be thereby magnified in Proportion. Therefore the common Rule for estimating the magnifying Power of Telescopes constructed with two Lenses, is the *Ratio of their focal Distances respectively*.

Euphros. I have a better Notion than I had of the Use and magnifying Power of a Telescope; but I am persuaded, if you could exemplify what you have said by an Experiment, it would still render the Nature of that Instrument more easy to be conceived.

Cleon. That I can easily do, in the following Manner;—— Here is a Telescope with two Lenses; that which is in the great End is called the *Object Lens*, as being next the Object when we view it; the other is called the *Eye-glass*, as being within a small Distance of the End to which the Eye is applied in using the Telescope:——* The Object Lens I take out of the Telescope, and fix it in a *Scioptric Ball and Socket*, placed firmly over a Hole in the Window-shut, made for that Purpose, and then putting the Window-shutters together, the Room is made dark,

* The Experiment of the SCIOPTIC BALL and Glasses in the *Camera Obscura*, is one of the most delightful in Optics, and those who have seen it, will readily understand all that is here said concerning the Nature and Effects of a Telescope; They who have not seen it, have it in their Power to purchase the Instrument at a small Price, and to try the Experiments without any Trouble; but they who have not Curiosity enough to do this, are deservedly excluded from participating in those Pleasures, which are the most exquisite that Nature affords, and place us at the greatest Distance from the Brute Creation,

and you see nothing but what comes through the Glass by Rays of Light from without.——A large, moveable Paper-screen, upon a Stand, is provided, and which I now place at the focal Distance of the Glass from the Window, which is in this Glass but 3 Feet;——Upon this Screen, you observe, there is instantly formed a beautiful Landscape of all the distant Scenes of natural Objects without.

Euphros, Indeed, I do; and a finer Picture was surely never seen.——What wondrous Painting is this!——I see the distant Fields and Meadows, with the meandrous Windings of the River!——I view every Thing in Motion, the People walking, the Cattle grazing, and the Ships sailing in the River.——The Objects all richly variegated with their natural Tints and Colours,——the Buildings all in Perspective, with a natural *Relievo* by Light and Shade!——I do not know that I was ever so delighted with a View of Nature at large, as I am with this Picture of it in Miniature,——and, upon the Whole, I cannot but observe how infinitely the beauteous Paintings from Nature's Pencil exceed the Imitations of those who copy her; and when I hear of the incredible Sums of Money that have been given for such inferior Performances, and at how small a Price those Glasses are purchased which present us with the inimitable Original, I am quite at a Loss to conjecture at the unaccountable Fate of Things.

Cleon. Most Things of this Nature you will always find very difficult to account for; and in all Subjects of this Nature which depend on the Fancy, Humour, or Caprice of Mankind, you will generally observe a very great Disproportion betwixt the real Worth, or intrinsic Value of the Thing, and the Price that is paid for it. But to return to the Subject;——You observe, in one Part of the Screen there is a round Hole, of about Half an Inch in Diameter, upon which any Part of the Picture may be thrown at Pleasure:——On the other Side of the Screen is made to slide over the Hole, a small Cell or Tube of Wood, containing a convex Lens whose focal Distance is one Inch and a Half, that also is the Distance of the Glass from the Hole; the Distance of the said Glass from the other End of the Tube is about an Inch,

Inch, to which End, if the Eye be applied, it will, by Means of that Glass, view those Parts of the Picture which fall upon the Hole in the Screen, and perceive them very distinctly; and, in viewing these, you view the Objects, of Course, to which they belong.—— You may, by placing yourself behind the Screen, try the Experiment immediately.

Euphros. I see perfectly well the Thing you mention.—— I see the Man walking by the River-side:—— I can easily distinguish the Colour of his Cloaths, his various Motions, and, what is very surprising, he seems extremely near, and walks with his Heels upwards.—— The same I observe of other Objects, when I move the Screen to bring them upon the Hole, as you have directed me.

Cleon. Your seeing the Object inverted, or upside-down, is a necessary Consequence of your viewing it in its Picture; for the whole Landscape is in an inverted Position, as you see; and therefore every Part, when viewed by the Glass, must appear in the Position it really has, viz. upside down.

Euphros. This I plainly perceive must be the Case; and I farther suppose, that the Reason why it appears so very near is, also, because its Image, by which I view it, is so very near to the Glass.

Cleon. That is the true Reason which you have assigned; and the Image, at that Distance from the Glass, subtending a much larger Angle, occasions your seeing every Part much more distinctly, than it could appear if viewed by the Eye at the Distance of the Glass in the Window; that is to say, it will appear as much larger, and more distinct in the former Case, than in the latter, as the Glass is there in Proportion nearer; for Instance, the Distance of the Eye-glass is but one Inch and a Half from the Image, but the Distance of the Object-glass in the Window-shut is 36 Inches. These two Distances are to each other as 1 to 24, and therefore the Image appears under an Angle 24 Times as large when viewed through the Eye-glass, as it does when viewed at the Distance of the Object-glass; and therefore it appears very plainly, from hence, that the Object will be seen under an Angle, when viewed in its Image, 24 Times

larger than it appears to the naked Eye, or just so large as it would appear at one 24th Part of the Distance that it is from the Window.

Euphros. Then if I understand you rightly, an Object at the Distance of 24 Rods, Furlongs, or Miles, will appear as plain in its Image, by Means of these two Glasses, as it would do to the naked Eye at the Distance of one Rod, Furlong, or Mile.

Cleon. That is the very Case: And from hence you will infer, that the Object is not improperly said to be magnified 24 Times.——Now, from all that we have here done in this darkened Room, the Reason will appear, why those Glasses are put together at each End of a long Tube to render them useful in the Form of a Telescope, *viz.* because the Space in which the Image of Objects are formed ought to be quite dark, or rather to have no other Light than that which enters the Glass and forms the Image of the Object.——This will appear by an Experiment; for if I open the other Shutters (letting that only remain shut which holds the Glass) then, because the broad Day-light falls on the Screen, the Images of the Landscape, which before were viewed strong and distinct, are now, by this Profusion of foreign Light, rendered faint, confused, and scarcely visible; and when you apply your Eye to the Glass, as before, behind the Screen, you scarcely perceive the Object for the dazzling Light which now overwhelms it.

Euphros. Well, let me try this Experiment.——I no sooner apply my Eye to the Glass than I perceive the Truth of what you say:——The Object is lost, in the Glare of Light, so far, that it can scarcely be said to appear.——I am hereby thoroughly convinced how necessary it is to exclude, from the Place where the Images of Objects are formed, all Light, but that which proceeds from the Object itself, in order to shew it distinctly.——But one Thing occurs which suggests the following Query: Pray, if the Hole in the Screen was larger, could I not see more of an Object, or more Objects than one, with equal Distinctness? For I think the View is very much confined by so small a Hole.

Cleon. Not with the same Eye-glass, my *Euphrosyne*; for, by Reason and Experiments, Opticians are taught

to make the Diameter of the Hole about $\frac{2}{3}$ of that of the Eye-glass, in order that the Image may appear distinct. This Hole is generally called the *Field of View*; and therefore if the Field be enlarged, the Diameter of the Eye-glass must be enlarged likewise, and also its focal Distance, of Course; for if you enlarge the Diameter, or Aperture of the Glass itself, you may soon exceed the Limit for distinct Vision, since every Glass has a limited Aperture as well in Telescopes as in Microscopes, as I have before observed to you.

Euphros. If this be the Case, what we gain by having a larger Field of View, we lose in the Power of magnifying; for since the focal Distance of the Eye-glass must be larger, it will not be so often contained in that of the Object-glass, and consequently the Object not appearing under so large an Angle, will not be so much magnified as before.

Cleon. With the same two Glasses you cannot enlarge the Field of View, and at the same Time preserve equal Distinctness and magnifying Power: You may, indeed, chuse two other Glasses whose focal Distances are increased in Proportion; for Instance, if the focal Distance of the Object-glass be 6 Feet, or 72 Inches, and that of the Eye-glass 3 Inches, each of them double of what we now use, in this Case the Aperture of the Eye-glass, and of the Hole, may also be enlarged to twice the Dimensions; but then the magnifying Power still remains the same, as also the Field of View; for though the Hole be enlarged, yet, because the Image is enlarged in the same Proportion, no more can fall upon that Hole than falls on this, and consequently no more of the Object can be seen: And if the Aperture of the Object-glass be made twice as large also, then there will be the same Degree of Light, or Brightness in the Object. — But one Thing you would observe in that Case, *viz.* that the Object appears more distinctly in all its Parts, for a very small Image will not appear so distinctly as a large One, under the same Angle, and with the same Degree of Light; and therefore the Power of magnifying, by Means of Object-glasses of a larger focal Distance, may be increased with sufficient Degrees of Brightness and Distinctness of Vision. Thus, for Experiment Sake, I will take that Glass from
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the Window-shut, and place another in its Room of double its focal Distance, viz 72 Inches; then remove the Screen to the same Distance from the Window, where now you see the Landscape greatly enlarged, twice as much in Length and Breadth, and therefore 4 Times as large in Surface as before; and as the Diameter of the Aperture of this Object-glass is twice as much as that of the former, there will be the same Quantity of Light in the Picture; so that each Image is now equally bright as before:—Then I apply a Glass of 3 Inches focal Distance behind, which will shew the Object under the same Angle as before, the Hole in the Screen being now twice as large.—Go, and apply your Eye to the Tube, my *Euphrosyne*, and tell me how it appears.

Euphros. I will.—By what you have said, Things ought to appear nearly the same as before.—But the Scene appears every Way more grand; and I cannot help thinking that the Objects severally appear not only more perfect, but also larger at the same Time.

Cleon. Your Observations are very just, except the last; the Objects are not in Reality magnified: This is a Deception of the Fancy; for we always imagine that the more illustrious any Thing appears, the larger it must be at the same Time.—That the View of every Part is more perfect, I will allow; for which Reason I shall shew you, by another Experiment, that the magnifying Power of the Eye-glass may be increased, by changing that which is now one of 3 Inches focal Distance, and substituting another in its Stead of 2 Inches only.—This is done: Take a View as before.

Euphros. I do; and cannot but say, the Objects appear sufficiently distinct, though magnified much more than before:—But they appear not altogether so lightsome, or bright.

Cleon. They are magnified now in Proportion as 2 to 72, or 1 to 36; and therefore the Power of magnifying now exceeds that in Proportion as 36 to 24.—But whereas you seem to think the Objects are now not bright enough, I must observe to you, that there is really more Light upon the Picture than is allowed of by the Laws of Optics or distinct Vision; for the Aperture of the Object-glass is now twice as large as before, whereas it ought to exceed

exceed the Aperture of the former Object-glass, but in the same Proportion as the focal Distance of the present Eye glass exceeds that before used: That is to say, in the Ratio of 3 to 2. Consequently, it will appear, from all that has been said, that though there be an Increase in the Power of magnifying in refracting Telescopes, yet in equal Degrees of Distinctness, a less Proportion of the Apertures in the Object-glass, or of Light in the Picture, will be necessary; and thus we may proceed till, at Length, the Degree of Brightness will become so far diminished as to render the Telescope but of very little Use in viewing terrestrial Objects, whose Light, when they become magnified to a great Degree, will be found too little to shew them sufficiently plain, with those Apertures of Object-glasses which are necessary for distinct Vision. ——— Having now explained at large, by these Experiments, the Nature of a refracting Telescope, and shewn that it is nothing more than a Sort of portable *Camera Obscura* in Miniature, I shall defer what I have farther to say, in Relation to the different Kinds and Constructions of this Instrument, to another Opportunity.

DIALOGUE VII.

On the various CONSTRUCTIONS of refracting TELESCOPES,

Euphrosyne.

YOUR last Lesson on the *Nature* and *Rationale* of refracting Telescopes, illustrated by Experiments of the *Camera Obscura*, gave me no small Delight, as I am well satisfied I could have, by no other Means, acquired so good a Notion of this entertaining Instrument; ——— I see you have here many different Sorts and Sizes upon the Table: I suppose, *Cleonicus*, they are the various Forms in which refracting Telescopes are now made.

Cleon. They are so, my *Euphrosyne*; and, that you may have a more distinct Idea of them, I shall enumerate them

them according to the different Names they bear, resulting from their different Structure and Uses.

I. The least Size of all is called an OPERA-GLASS, from its being principally used in the *Opera*, and Play-houses.

II. The PERSPECTIVE GLASS, which is only the former Glass less in Diameter, but of a greater Length, and fitted for the Pocket: This is also, by Opticians, called *Galileo's Telescope*.

III. The *Astronomical* TELESCOPE, so called, as being chiefly appropriated to celestial Observations.

IV. The common TELESCOPE, adapted for viewing Land-Objects.

V. *Sea* TELESCOPES, constructed for viewing Objects at *Sea* most conveniently.

There are, besides these, other Constructions of this Instrument, which are called, *Helioscopes*, *Polemoscopes*, &c.

Euphros. I suppose the first that you mentioned, and called an *Opera-glass*, is this very short one, with a broad Glass at the End; it seems very fit for the Purposes intended, as it may be easily held in the Hand and applied to the Eye.

Cleon. Yes, my *Euphrosyne*, that is the first Sort of prospective Glass, and consists only of two Lenses, one of which is the broad Glass you speak of at the End, called the Object-glass, and is a Plano-convex; the Glass at the other End is a Plano-concave, and is to be drawn out, or in, by Means of the sliding Part, or Drawer; by this Means, the two Glasses are adjusted to a proper Distance for viewing Objects.

Euphros. What are the particular Properties of this Sort of Telescope?

Cleon. First, the Concave-glass is placed within the focal Distance of the Object-glass, by just so much as is equal to its own focal Distance; and when they are in this Position, the Rays proceeding from the Object, will, by Refraction through this Instrument, be made to fall parallel upon the Eye, and thereby a distinct Image will be formed on the optic Nerve, which is necessary for perfect Vision.—Secondly, the Object-glass at the End has generally a very large Aperture, to give sufficient

Light

Light for viewing the Object, especially as it is chiefly used by Candle-light: But for strong Day-light, and viewing Objects enlightened by the Sun, the Aperture at the Object End ought not to be so large, as the Object, in such Cases, is liable to be very much coloured and less distinct.——Thirdly, the Aperture of the Concave, next the Eye, is, or ought to be, always small, *viz.* but a little bigger than the Pupil of the Eye.——Fourthly, as the Eye-glass is placed within the Focus of the Object-glass, the Length is less, for the same Power of magnifying, than in any other Telescope.——Fifthly, as there are but two Glasses in this Construction, and each of them of the best Form, it renders Vision in this Instrument most perfect; for that is always more so in Proportion as the Number of Glasses is less, because, by Refraction at every Glass, some Irregularities are produced which disturb the Sight, or render the Image less perfect.

Euphros. When I look through this Glass, I can scarcely imagine it magnifies at all.

Cleon. That is the Case with most People when they first use these Instruments: they often say as you do; nay, some of them will affirm, that they can see better without the Glass than with it: But these are all Mistakes, or Deceptions of Vision; for these Glasses, all of them, magnify Objects 3 or 4 Times, and there is no Form of the Eye but what may be assisted by its Use, when it is properly applied.——The Proportion of magnifying is here the same as of the two Lenses I used in the dark Room; for whether the Eye-glass be Concave, or Convex, it makes no Alteration in that Respect; for the Power of magnifying by any two Lenses will be proportioned to their focal Distances.—Thus the Object-lens, here used, is 3 Inches focal Distance, and the Concave, next the Eye, has but one Inch focal Distance: Therefore this Opera-glass magnifies in Proportion as *three to one*, or *three Times*.

Euphros. I must not pretend to contradict you; but, really, Objects do not appear to be so much magnified to me. Pray, *Cleonicus*, have you any Method by which you can satisfy me of the Truth of this by Experiment? — You will excuse my being so troublesome.

Cleon. It always gives me the greatest Pleasure to satisfy the scrupulous Curiosity of Ladies and Gentlemen in this Respect:——And the Method I take to convince them in general is, that which I have here provided for you; for I foresaw you would make this Objection.—You see here, a Piece of white Paper, just 3 Inches long, and the Inches defined by black Lines——I stick it up on the opposite Side of the Room, for you to view it through the Glass,——and when you see the Paper distinctly in the Glass, open the other Eye and view it by that, without the Glass, and you will observe, that one Inch of the Paper, seen through the Glass, will appear just as long as the whole Length of the Paper appears to the naked Eye.

Euphros. Let me try this Experiment forthwith, as it is so very easy.——I have adjusted the Glass, and can plainly see the Paper through it.——Now I'll open my other Eye, and direct it to the Paper;——and, upon my Word, to my Surprise, I find the Thing you mention to be fact.——I actually see one Inch of the Paper, through the Glass, just covers the whole Length of the Paper as viewed by the naked Eye, and, of Course, the whole Paper appears 3 Times larger with, than without the Glass, which I could not have believed if I had not tried the Experiment.—I am, by this Instance, fully satisfied how much we are liable to be mistaken, and to form wrong Ideas of Things, for want of proper Methods to inform the Judgment.—As you have been so obliging as to make me a Present of this curious Opera-glass, please to let me know if there are any Precautions to be given for the Use of it.

Cleon. It will be necessary to observe the following Particulars:—First, in adjusting the Glasses, you draw out the Tube to the black Circle which is drawn upon it, and then it is adjusted for Objects at a moderate Distance.——Secondly, but if Objects are very near, the Tube must be drawn a little farther out, and, on the contrary, not quite so far as the Circle, for Objects at a great Distance; but you will never be perfect in the Use of this, or any other Telescope, till you can readily adjust it by moving the Tube forward and backward, while you are actually viewing the Object through it, and stop your
Hand

Hand when you find the Object appear most perfect.—

Thirdly, when you have Occasion to take the Glasses out to clean them, you will remember always, when you put them in again, to place the Object-glass with its convex Part outward, and the Eye-glass with the concave Part next the Eye, and then it will be always fit for Use.

Euphras. I am obliged to you for these Instructions.— But here is the other Glass you called *Galileo's Telescope*, pray, what are the Properties of that Construction, and how am I to proceed in its Use?

Cleon. This is in nothing materially different from the other, but in its *Length* and *magnifying Power* in Consequence thereof; for as the Object-glass here has a longer focal Distance in Comparison of that of the Eye-glass, it will, of Course, have a *greater* Power of magnifying in Proportion.—This, which I here present you with, is a proper Size for the Pocket, and will magnify sufficiently for common Use. The Object-glass is 12 Inches Focus, and magnifies the Object about ten Times: But there will always be an Inconvenience attending the great Length of an Instrument of this Kind, *viz.* the Smallness of the Field of View, which is here proportioned to the Area of the Pupil of the Eye; and therefore, when it magnifies much, the Field of View will be but small, and render it more difficult to find the Object, and less pleasant to view it:—Were it not for this Impediment, no Telescope would shew distant Objects so perfectly as this, on Account of there being but two Glasses in the Construction.—But in Case the distant Objects be very small, such as the heavenly Bodies are in Appearance, then *Galileo's* Telescope is applied oftentimes to very good Purpose; for, with that, the Sun, the Moon, and the Planets will be magnified very considerably in a Length of 18 Inches, or two Feet, even so far as to shew *Jupiter* and his four Moons, which cannot be done with other refracting Telescopes of less than twice that Length; but even in viewing the celestial Bodies, if we proceed to great Lengths in the *Galilean* Telescope, the Difficulty of finding the Object will frustrate our Designs, and oblige us to have Recourse to the other Forms of Telescopes, next to be considered.

Euphros. I think the first of them you call the *astronomical Telescope*, as being designed for viewing the heavenly Bodies only?

Cleon. Yes: that is the first and most simple Construction of Telescopes composed of convex Lenses only, of which there are but two or three at most.—But, as in these Sort of Telescopes there is a real Image formed of a distant Object in the Focus of the first, or Object-glass, which Image is viewed by the Eye glass in the Manner I shewed you in the darkened Room, it is evident, that this Instrument shews all Objects in an inverted Position, and therefore not fit for common Use, as I then observed to you; but the heavenly Bodies being of a round, or circular Form, the Inversion of such a Figure is no Disadvantage to the View; and since the Appearance of an Object through two Glasses is most perfect, and the Moons of *Jupiter* and *Saturn* require the most perfect Construction to shew them, this Telescope is preferable to all others on this Account, as the Field of View is large, and the Object found with Ease.—In this Telescope one Object-glass is sufficient, though in some Respects two may do better.—There is also, generally speaking, but one Eye-glass used; but it is certain, from the Laws of Optics, that two Glasses properly combined will shew the Image (and consequently the Object) more perfectly than one alone*.

Euphros. I remember you told me the magnifying Power, by Means of these two Glasses, was in Proportion of their focal Distances:—But one Thing I am not quite so clear in, is, the Reason why the Images of Objects are inverted in the Focus of the Object-glass, and whether there be not any Method to prevent that disadvantageous Effect?

Cleon. The Reason why the Image of an Object is inverted by a Glass you will readily perceive, when you consider, that every Point of the Image is depicted by a Ray of Light coming from the Object in a right-lined Direction through the Centre of the Glass; from whence

* For the Demonstration of this physical Problem in Optics, see my *New Elements of Optics*, p. 33, 34.

it will follow, that those Rays of Light which come from the upper Part of an Object must, after passing through the Center of the Glass, go to the lower Part of the Screen, and there paint the Image of the upper Part of the Object.—On the other Hand, the Rays which come from the lower Part of the Object, after passing through the Center of the Glass, go to the upper Part of the Screen, and there form an Image of the inferior Parts of the Object:—And, by the Laws of Refraction, all other Rays which proceed from the same Points in the upper, or lower Parts of the Object, to any Part of the Lens, will be refracted to the same Points of the lower, or upper Part of the Image, and there unite with those Rays which pass through the Center of the Glass; consequently, the Image, by Means of the Rays crossing each other in the Glass, must necessarily be formed in an inverted Position, and which, you remember, was universally the Case in all single Lenses you tried in the former Experiments.

Euphrosi. I remember this to be fact in every Instance I tried, and, as it is a great Imperfection in the Telescope, could it not be removed by applying another *Object-glass*?

Cleon. By no Means: Any Number of Object-glasses will form an Image in the same Manner, as one alone:—But the Image will still be inverted, and only lessened in its Dimensions; so that no Redress for this Evil can be had from thence.—Yet are we not destitute of a Remedy, which is found in the Construction of the common Telescope, and is what I next propose to explain, after having proposed to you one Thing more, which is, the Reason why the Construction of the Telescope under Consideration, is also sometimes called the *Night Telescope*; for when the Aperture of the Object-glass is very large, and the Glass itself of a short focal Distance, as 8 or 10 Inches only, then the Field of View will be very large, and by Night, at Sea, there will be Light enough in the Atmosphere, and by Reflection from the salt Water, to enter through so large an Aperture as will be sufficient to shew Objects, on the Surface of the Sea, at a considerable Distance; at least, much better than they can be discerned by the naked Eye, and thereby such a Telescope becomes

of general Use at Sea — But when the focal Distance of an Object-glass is short, and so large an Aperture used, it becomes necessary to use two Object-glasses, that the Errors of Refraction, arising from the Convex Figure, may be in some measure corrected, and Vision thereby rendered more distinct. — And in the largest Sort of Night Telescopes, where the Aperture is very large, no less than three Object-glasses are necessary to form the Image, on that Account.

Euphros. 'Tis easy to observe in this, as in many other Cases, that Necessity is the Mother of Invention; and had you not given me this *Rationale* of it, I should have thought you had jested with me, in talking about a Night Telescope, as it is well known by Experiment, that every Telescope makes the Object appear less lightsome than it appears to the naked Eye, and therefore it should seem a Contradiction to have a Telescope for viewing opake Objects by Night. — I suppose, the Telescopes I here see of different Sizes are all *Day Telescopes* of the common Forms in Use?

Cleon. They are, my *Euphrosyne*; but some of them have more Glasses than others, and all of them shew the Object upright, or in its natural Position: But the least Number of Glasses, in any of them, is four. — You see, here is one at the Object End, — and in the Drawer next the Eye, you observe this Tube with three Glasses is contained.

Euphros. So that in all the four-glass Telescopes I observe there are three Eye-glasses, and one Object-glass; but, pray, why are three placed next the Eye, *Cleonicus*?

Cleon. That you may have a clear Idea of this Matter you are to consider,

(1.) That the first Image is formed in the common Focus of the Object-glass, and the first of the three Eye-glasses; and therefore,

(2.) The Rays which proceed from this Image to the first Eye-glass, are, after Refraction through it, rendered parallel among themselves; and, consequently, if they fall upon a second Glass, placed at a Distance behind it towards the Eye, they will be all converged to a Point in the Focus of that Glass, and, for this Reason,

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(3.) Rays thus proceeding from every Point in the first Image will, by Refraction through the two first Eye-glasses, form an Image at a proper Focus which will be every Way similar to the first Image.

(4.) The two first Eye glasses being placed at double their focal Distances from each other, will then have the most proper Position for producing the Effect; because then the Rays that proceed from contrary Sides, in the first Image, through the first Eye-glass, will be so refracted as to cross each other in its Focus, and consequently fall upon the second Eye-glass in a manner just contrary to that in which they proceed from the first; and therefore the Image formed by Refraction through the second, or middle Glass, will be in a contrary Position to the first Image, and therefore in the same Position with the Object itself. Hence,

(5.) An Image of the Object being now formed upright, that Image is so viewed by the third Eye-glass, or that next the Eye, which, for that Reason, must be placed at its focal Distance from it, that the Rays may proceed parallel to the Eye.

(6.) The three Eye-glasses are all of them of one and the same focal Distance, and therefore the Distance between each of them will be the same, as you see they are placed in this Tube.

(7.) Upon this Account it is evident, that the second Image is viewed under the same Angle by the third Eye-glass as the first Image appears under when viewed by the first Eye-glass; and therefore the Power of magnifying is the same with three Eye-glasses as it was with one in the astronomical Telescope.

(8.) In the Place where the second Image is formed is a Diaphragm, or round Hole in a Piece of Wood, or Brass, of a Size somewhat less than the Area of the Eye-glasses, in order to shut out all the extraneous Rays, or to shew that Part of the Image only which is sufficiently perfect for View.

(9.) And where great Nicety is required, there is also a Diaphragm with a small Hole, of a proper Size, to be placed in the common Focus between the first and second Eye-glasses; and if the first Image were circumscribed by a proper Aperture in another Diaphragm, it would

tend to render Vision through a Telescope still more perfect.

(10.) And lastly, the Field of View in this Sort of Telescope is the whole Area, or Aperture of the Diaphragm next the Eye, and therefore as much larger than what you have in the *Galilean* Telescope, as the said Aperture here is larger than the Pupil of the Eye.———And such is the Construction and *Rationale* of the common refracting Telescope, which neither you, nor no one else could properly comprehend without actually viewing the several Parts of the Instruments themselves.

Euphros. I am thoroughly sensible of that; for it is here as with the Microscopes, unless we see the Form and Position of the several Parts separately, it is impossible to have an adequate Idea of the joint Effect of the Whole, in the Structure of Instruments.———And, after all, I find that this refracting Telescope does nothing more than the former, but *shew the Object upright*, which is certainly a very great Improvement upon the *Galilean* Telescope, in regard to the Amplification of the Field of View.———But at present I must desist, to attend another Engagement, and will give you the Trouble to prosecute what remains, relative to this Subject, at our next Leisure*.

* *N. B.* The Telescopes described in the above Dialogue I have thought proper to illustrate by a Copper plate, representing the Sun-Beams entering through Scioptic Balls into a darkened Room, and refracted through the Object-glasses of Telescopes fixed in circular Frames, perpendicularly, on long Pieces of Wood screwed on to the said Balls: and at the other End of the said Pieces of Wood are placed the Eye-glasses, at proper Distances from the Object-glasses, and from each other; by which it appears, that each Telescope produces the same Effect of refracting the Rays to proper Focuses, and, at last, rendering them parallel to the Eye, by which distinct Vision is produced. The first, or uppermost of these, represents the Glasses of the *Galilean* Telescope.———The Second, the astronomical Telescope.———The Third is the four-glass Telescope.———The Fourth is the Night-Telescope. If the Glasses of any of these Telescopes were to be thus placed in a darkened Room, the Beam of the Sun's Light would pass through them in the same Manner as here represented.

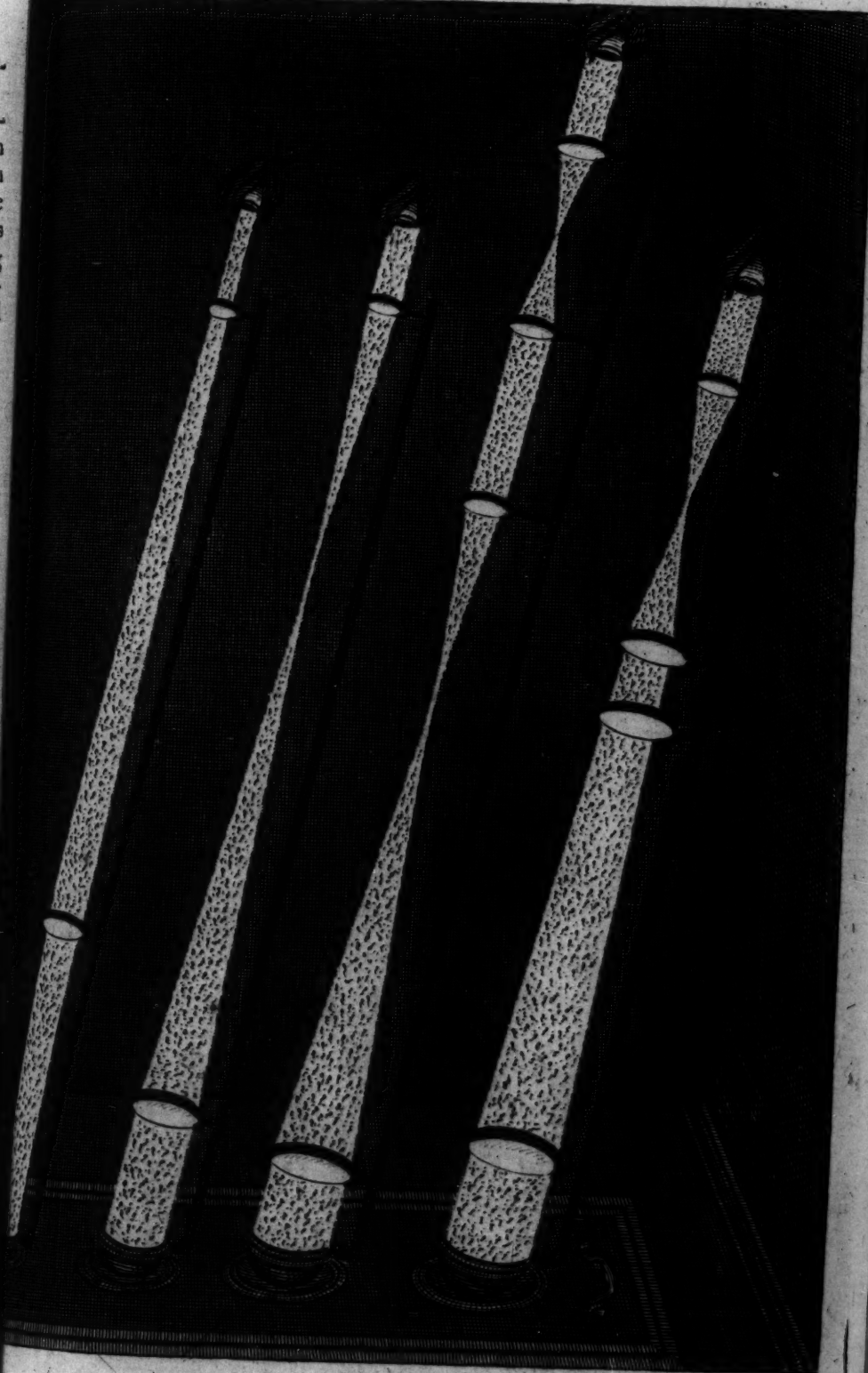
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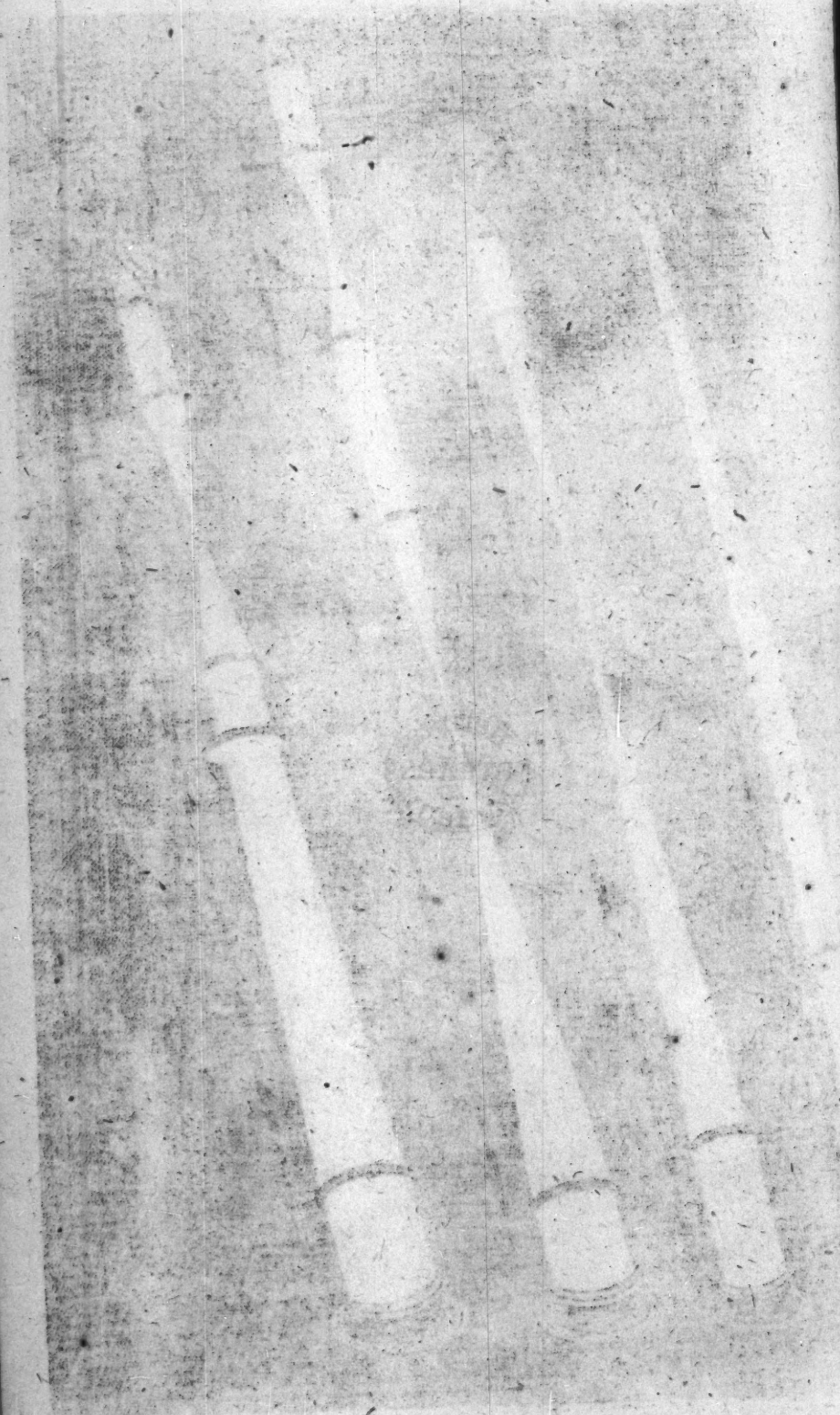
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D I A L O G U E VIII.

*The NATURE and CONSTRUCTION of refracting
TELESCOPES continued.*

Euphrosyne.

I Am now ready to attend you, *Cleonicus*, in what you have farther to say upon the Subject of refracting Telescopes.—You have already described to me the four principal Forms, the last of which was one of four Glasses; but I remember you said, there were other Telescopes that had more than four Glasses; please to let me know what Purpose the additional Glasses answer?

Cleon. In some there are five, and in others there are six Glasses, which are principally intended to *enlarge the Field of View*, and to render the Image more perfect towards the extreme Parts: The Disposition of the Glasses is different in many of them; but, in general, it is the same as what you see in this, which I here put into your Hand:—And that you may see the Difference between this, and a four-glass Telescope of the same Length, you have now an Opportunity of viewing the Cross, the Globe, or Ball, and the Dome of *St. Paul's*, the Sun lying advantageously upon them.

Euphros. These Telescopes, I see, are about three Feet in Length, and I shall gladly experience their Difference.—First, I will take the four-glass Telescope, —with this I see the golden Cross, curiously wrought, and very large and distinct.—The Ball appears very grand, as well as globular, with curious Workmanship, —and the Golden-gallery appears like what it is when we are upon it: I can easily distinguish Men and Women, their different Habits, Colour of their Cloaths, some of them walking, and others leaning over the Palisades.—The Dome appears to be a glorious *Rotundo*, and every other Part in Proportion, exhibits an agreeable Spectacle. —I will now take the Telescope with six Glasses, —and, in viewing the same Objects, I perceive a Difference in the Extent of the View, which is certainly, here much larger and finer than before; but,

at the same Time, I do not think the several Parts appear so very distinct as in the former,——and, on that Account, I really do not know which of the two I should chuse.

Cleon. You need give yourself no Trouble about that, my *Euphrosyne*; for I shall make you a Present of them both:——They have each their peculiar Advantages, and you never will find any one Instrument in which the different Perfections of various Forms can be all united.

Euphros. I readily believe what you say: But what are those long Telescopes in Mahogany, and coloured Wood?——Are they not what you call *Sea-Telescopes*, *Cleonicus*?

Cleon. Yes, my *Euphrosyne*, they are, and used chiefly by Masters of Vessels, and other Sea-faring People, for as they are all in one entire Length, they give them no Trouble, and require no Time in applying them to use; This renders them more fit for their Purpose, who oftentimes have not a Moment to spare, when their Use is required, for viewing a Ship, Headland, Lights, &c. at the first Appearance. Add to this, that Vellum, or Parchment Tubes, of which common Telescopes are made, will not bear the Action of a saline Atmosphere, which soon discolours them, destroys their Texture, and renders them unfit for Use, unless they are taken very great Care of indeed, and kept in proper Cases.

Euphros. But I see here a Telescope somewhat different from the former, especially at the Object-end, the Brass-work of which I perceive to be of a square Form; to what Purpose does that serve, *Cleonicus*?

Cleon. That Object end of the Sea-Telescope is made in the Form of a Dye, on Account of its holding two Glasses; either of which may be immediately applied, as an Object-glass, by turning the Place round in which they are contained, which is done in an Instant, by a proper Mechanism in that Part: by this Means you have, as it were, a double Telescope in one Instrument; for the Glasses being of a different focal Distance, and the Brass Tube being made to draw out at the Object-end as well as the Eye-end, the Telescope may be lengthened, or shortened, at Pleasure, according to the Object-glass that

is used:—But when we consider, that such a Telescope becomes, by this Construction, so expensive, as to equal the Price of three very good single Telescopes, at the same Time each of which may have a different Power of magnifying, it appears to me to be a very preposterous and an injudicious Contrivance, and, as such, deserves no farther Notice.

Euphras. There is yet another Telescope which makes a considerable Appearance, concerning which you have not said any Thing. Pray, is the internal Structure of this different from any of the former, as I see nothing different in its external Form?

Cleon. This is a Patent Telescope, and different from others in having a double Object-glass, one convex and the other concave, placed contiguous to each other in the same Cell: The spherical Figure of which is different in each, and the Design of such a Combination of Glasses is, that one may correct the Errors of the other, in regard to the colorific Refraction of Light; for whereas you have been taught by prismatic Experiments, that Rays of Light have different Degrees of Refrangibility, and I have not long since observed to you, that this is one great Cause of the Imperfection of refracting Telescopes with a single Object-lens of a convex Form, therefore this concave is added to correct this Aberration of Rays, and to render the Image of external Objects more perfect and uniform.

Euphras. And do those two Glasses answer such a Purpose in a sensible Degree?

Cleon. You will have no Occasion to take my Word, or Opinion, about this Matter, because you may try the Experiment yourself, and see the Difference betwixt this and another of the same Length and magnifying Power. —I have here contrived to place them both in a Position, to view the same distant Object, which happens very *apropos* to be the Cross on the Top of St. Paul's, in a direct View.

Euphras. The Cross makes a very curious Spectacle; and I observe, very plainly, that there is a Difference, but not so great as I should have imagined, from the very great Difference which you mention in the Price of these two Telescopes. ————— There is (*je ne scai quoi*) some

something which I cannot well express, in the Effect of this Telescope ——— I see the Crois and its Parts more perfectly in one respect, yet not so much so in another.

——— But there seems to be so much of Ambiguity in the different Effects of these Telescopes, that I must be longer exercised in the Comparison of them before I can pretend to form any adequate Notion of their respective Merits, or how much one is preferable to the other. ——— But, pray, what is that particular Construction of a Telescope you call a *Polemoscope*?

Cleon. By that Term is meant, a Telescope, at the Object-end of which is fitted a very curious reflecting plain Speculum at half a Right-angle to the Axis of the Telescope, which is directed to the middle Point of the said Speculum, as you observe in this Part which I screw off and on.

Euphros. But what is implied in the particular Etymology of the Word?

Cleon. The Name implies an Instrument of the Telescopic-kind, for the Uses of *War*; that is to say, such, as the Generals, or Officers concerned in Sieges, Fortifications, &c. have often Occasion to use: For, in many Cases, besides a direct View strait forward, they have often Occasion to see what is doing by Persons on either Side, above, or below the Place where they stand, and which, with this Contrivance, they can easily command a View of; for, as you turn the Glass in your-Hand, you take in all Objects in a lateral Situation, or such as are placed Side-ways, and cannot be seen by a common Telescope. ——— If you turn the Speculum downward, you see all below; ——— if you turn it upwards, the Top of the Buildings, and the People there, are exposed to your View: And thus the Actions of the Enemy may be reconnoitred, while they think themselves quite secure from your Notice.

Euphros. Why, after all your learned Terms, I find that this high-sounding Instrument is nothing more than the common Opera-glass, which a Lady of my Acquaintance shewed me the other Day, having a Hole on each Side, in which there appears a plain Looking-glass adapted to each End, and by which she could take a View of any Person she pleased, without his having the least Suspicion

of it, as the Glas was directed quite another Way. I cannot say but I was very much pleased with the Effect, and wished for such a one of my own.

Cleon. Then here you have your Wish, my *Euphrosyne*; for I have designedly procured such a small collateral Operaglass on Purpose to exemplify the Use of the other more at large, since Side-views may oftentimes be agreeable and useful to the Fair-Sex, as well as necessary to military Officers. Thus, both the one and the other you have in your Possession, to use at your Pleasure.

Euphros. You will greatly enrich me with an Apparatus of such curious Instruments.——But I remember, in the last Place, you mentioned another Sort of optical Instruments, you called HELIOSCOPES, pray, what are they?

Cleon. They are still of the Telescope Kind, and are so contrived as to give a very pleasant and inoffensive View of the Sun, whose ardent Lustre is much too great to admit him an Object of the common Telescope.——It is necessary, one Way or other, to weaken, or obscure his Rays, that our Eyes may behold the most illustrious Object of Nature;——there are many Ways of doing this, the most common is, to hold one of the Eye-glasses of a common four-glass Telescope over the Flame of a Candle till it is thereby rendered sufficiently black, to view the Disk of the Sun without hurting the Eyes, which will do pretty well for common Use:——Another Method is, by placing a Piece of stained Glas, of a very deep, dark Colour, in the Brass Cell next the Eye, which will answer the same End and with less Trouble:——But the best, and most perfect Method of making a Helioscope is, to weaken the Rays of the Sun by many Reflections, forward and backward, from Surface to Surface of a proper Number of plain, polished Speculums, till, at last, they are rendered so faint, that the Eye may sustain their Effect without any Trouble or Inconvenience, and the Face of the Sun will appear, in this Way, so very serene and distinct in every Part, that the *Maculae*, and *Faculae*, i. e. the dark Spots, and the brighter Parts, will, this Way, appear to the greatest Perfection: This is one of the many celebrated Inventions of the late Dr. *Hooke*.

Euphros. The Subject of Telescopes, I find, is very extensive, and admits of great Variety.—Are there any other Forms or Denominations of this Instrument which remain to be considered?

Cleon. Yes; one very material one, called the *solar Telescope*, and which will afford you no small Amusement at your leisure Hours, in a darkened Room.—This Instrument is no other than a *Galilean Telescope*, screwed into a scioptric Ball, moveable in its Socket, fastened to the Window-shut.—Walk but into the little Parlour, which is already darkened, and there you will see its delightful Effects.

Euphros. And what am I to see now I am here, *Cleonicus*? At present I observe only a Beam of the Sun's Light coming through the Instrument.

Cleon. That Beam of Light is to pass through this small prospective Glass, when screwed into the Hole of the Ball, and in such a Manner, that when the Rays proceed from it, they will form a very large and beautiful Image upon the Screen, which you there see placed on purpose to receive it.—I have now screwed it on, and you observe the Effect of it as a Helioscope; for this is one of those Helioscopes which Dr. *Hooke*, in his Treatise on this Subject, recommends, and it is, in his Opinion, the best Method of forming the Sun's Image.

Euphros. I cannot but admire the Effect of it, in producing so curious a Picture of the Sun:—How large and well defined a Circle it makes,—in its own native and pure white Light!—The Spots, how plain and distinct they appear!—and the Clouds, how quick and how natural they are in Motion, upon the Sun's Disk!—I think this is every whit as perfect as that which I saw by the reflecting Telescope some Time ago, which you purposely contrive to oblige me with an artificial View of the Transit of *Venus*:—But now the Time is at Hand, when we are to view that glorious Phenomenon in Reality, will not this Experiment, by *Galileo's Telescope*, be sufficient to answer that Purpose?

Cleon. If not the most perfect and ready Way of exhibiting that Phenomenon, it seems to have been this
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very Method that Mr. HORROX himself made use of, to observe the Transit of *Venus* in 1639; for he tells us, he observed the Planet *Venus* on the Face of the Sun, by Means of his Telescope, in his darkened Chamber. Now, there could be no Necessity for his darkening the Room for observing the Sun, by a Telescope, any other Way than this; nor is it in any Degree necessary even here, but only for greater Distinctness; for, at the Time of the Transit, the Planet will be seen sufficiently plain, as you may judge by the Appearance which the Spots of the Sun now make when I open the Window-shutters and let the Light into the Room.——I have now opened the Window, that you may see the Experiment both Ways, *viz.* in the darkened and enlightened Room, at once.

Euphros. I am fully convinced, by this Experiment, that scarce any thing more is necessary to shew the Spots upon the Sun than only some Contrivance to keep off the Sun-beams, and the direct Light from falling upon the Screen, in any Sort of Telescope or Helioscope whatsoever.—Would not this be a very good Way, *Cleonicus*, to observe a solar Eclipse?

Cleon. The last considerable Eclipse of the Sun I shewed this Way, to a great Number of Spectators, who were all greatly pleased in viewing it in so advantageous, and, at the same Time, so inoffensive a Manner: And thus, also, you may view the approaching great Eclipse in 1764.——But for my own Part, when I want to satisfy my Curiosity with a View of the solar Spots, &c. I give myself no trouble in darkening of a Room, but do it either by the reflecting Telescope, in the Manner I formerly shewed you, or else by this small Telescope, in a Ball and Socket, fixed to a Board, which I place near the Side of a Table on a proper Stand, and, as it darkens the Screen, gives me an Opportunity of viewing the solar Disk, Spots, and Clouds, just as you now observe.

Euphros. I see you have many Inventions to gratify the few who have any Taste for natural Curiosities, or think it worth while to observe the Wonders of Nature.

Cleon. You have as yet seen but one Part of those optical Instruments, we call Telescopes; but there is another

another Sort yet, more perfect than these, which we call reflecting Telescopes, the external Form of which you are no Stranger to; but the Nature and Structure of this Instrument being very peculiar and delicate, I shall endeavour to give you an Idea of it the next Opportunity we have to converse upon these Subjects, together with some Account of their Origin and Invention.

DIALOGUE IX.

*Of the NATURE, ORIGIN, CONSTRUCTION, and
USE of reflecting TELESCOPES.*

Gleonicus.

IN our former Conversation, I have observed to you a very material Defect in the Nature of refracting Telescopes, *viz.* that they refract not all the Rays of Light to a single Point, as they ought to do, for the Perfection of Vision, both on Account of the Figure of the Lenses, and of the different Refrangibility of the Rays of Light; and, in the very great magnifying Powers required for celestial Observations, their great Length renders them unwieldy, and consequently very inconvenient for Use: And this proved the general Reason for the Invention of Telescopes by Reflection, which are, generally speaking, called CATOPTRIC TELESCOPES.

Euphros. I remember you have often mentioned this Affair: But let me ask you one Question concerning long Refractors. Pray, have not all the Skill and Ingenuity of Opticians been able to contrive a Contraction of their immoderate Length, so as to render them more easy to be used?

Gleon. Many Attempts of this Kind have been made; but the most remarkable were those invented by *Dr. Hook*, under the Name of HELIOSCOPES, which he effected by various Reflections, from plain Speculums which he placed in a long square Tube; so that if these Reflections were made from End to End, he shews (to use his own Words) how $\frac{1}{2}$ of the Length of the common Tubes

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may be taken away by four Reflections.——But we do not find that this ingenious Invention of the Doctor's ever obtained so far as to be of general Use: It is probable it might be owing to the imperfect Manner of making and polishing the Speculums a hundred Years ago; and that if the same Method were to be now revived, it might be attended with better Success: But this only by-the-bye.

——Reflecting Telescopes are undoubtedly the best *Succedaneum* to Refractors.

Euphros. Pray, who was the first Inventor of Telescopes by Reflection?

Cleon. The first who has given us any direct Account of this excellent Invention was Dr. *James Gregory*, in his Book entitled *Optica Promota*, which was printed in the Year 1663. He has there (Page 94,) given us a Figure of the said Telescope, very much the same Form with those we have now in Use, *viz.* consisting of one large, and one small reflecting concave Speculum, and one Lens in a Piece at the End, whence it will appear with how much Propriety this Form is called, the *Gregorian Telescope*. But with Regard to the great Speculum in this original Telescope, it seems to have been made of Glass, and was of a *parabolical* Figure. The small Speculum, he tells us, was *elliptical*; but afterwards he allows, that, considering the Difficulty of acquiring these Figures mechanically, Speculums of a spherical Form will do very well.

Euphros. I always had a Notion, that Sir *Isaac Newton* was the Inventor of the reflecting Telescope: Pray, is not this the common Opinion?

Cleon. Most People have such a Notion; but it rather proceeds from his Improvement, or the Method which he took to bring them into common Use: For that great Man did, for a long Time, labour with his own Hands, both in grinding Mirrors, in Metal and Glass, of a spherical Form, and constructed a Telescope with Speculums of his own Working; and, lastly, gave a general *Rationale* of the Whole: From whence the World was first taught the Nature of Vision by Reflection, and how much it is preferable to that by Refraction; and therefore the THEORY of the Instrument, especially the comparative Part, we owe to Sir ISAAC NEWTON.

Euphros. Pray, wherein does the great Excellency of a reflecting Telescope consist?

Cleon. In this one Particular, that since (as I heretofore shewed you) the Angles of the incident and reflected Ray are ever equal, therefore Rays of every different Sort falling upon a Speculum, very near to its Axis, will all be reflected to one Point therein, at least so nearly, that the Difference is not sensible in any Experiments of Vision; and therefore all that Imperfection arising from the colorific Quality of Rays, in refracting Telescopes, has here no Place; nor is the Error, from the Figure of the Speculum, any Thing like so great as that from the Figure of Lenses: These Telescopes, therefore, are as perfect in their Nature as any Thing of this Kind can be.

Euphros. Methinks I should be very glad to have an Idea of the particular Manner in which Vision is produced, or the Object formed in a reflecting Telescope.

Cleon. I will give you as particular an Account thereof as possibly I can, and illustrate each Part by an Experiment.

First, with respect to reflected parallel Rays, you must know that their Focus, or Point, where the Image is formed, is just a fourth Part of the Diameter of a Sphere, of which the great Speculum is a Segment. Thus, for Instance, you see a metalline Speculum, which I take out of this Reflector, and holding it in the Sun-beams, they are all reflected to a Focus, at 9 Inches from the Speculum, as you see measured by the common Foot-rule; and therefore the Diameter of the concave Sphere, of which this Speculum is a small Portion, is 4 Times 9, or 36 Inches in Diameter.

Euphros. All this I perceive very plainly; and the Image of Objects formed by such a Speculum is, I suppose, equal to that made by a Lens of 9 Inches focal Distance.

Cleon. It is so; and since the Image and Object both appear under the same Angle from the Vertex of the Mirror, we may reckon the magnifying Power, by the first Reflection, to be 9 Times: Which may be demonstrated after the same Manner as I formerly shewed by Lenses, which I shall likewise now shew you by Experiment.

ment. For the small Speculum, which you observe at the other End of the Tube, has it focal Distance just one Inch, and therefore if placed just 10 Inches from the great Speculum, by Means of the Wire-screw at the Side of the Telescope, then will the Image be in the common Focus of both the Speculums; the Rays therefore which proceed from the Image to the small Speculum will be reflected by it, parallel among themselves, through the Hole of the large one; and therefore, if your Eye be placed in those parallel Rays, you will see the Object most perfectly in the small Speculum, and magnified in Proportion to the focal Distances of the two Metals, that is to say, as 9 to 1.—I will take off the Eye-piece, then apply your Eye to the Hole, and turn the Screw till you see the Object plain.

Euphros. Let me try this Experiment;———I do as you direct me;———at length I see the Object very distinct, very perfectly, indeed:———But I see no more than what is in the Face of the small Metal, and therefore the Field of View is very small:———I also observe it is magnified; but I should not have thought it was 9 Times larger than the Object.———I likewise see every Thing upside down.———On all which Accounts, this seems not to be the best Method of viewing Objects.

Cleon. You are so far right, my *Euphrosyne*; the Field of View must necessarily be small, as the Eye must be placed so far from the small Speculum;———the Image must necessarily be inverted, as the Rays cross each other in the common Focus of the Mirrors:———But your imagining the Object not to be so much magnified, is one of the most usual Fallacies of Vision; for the Objects must ever be magnified in the Proportion of the focal Distances of the Mirrors.—The two Metals, as they are thus combined, are exactly analogous to the astronomical Refractor, except that in the latter, your Eye may be placed near the small Lens, and by that Means you have an amplified Field of View.

Euphros. The small Brass Tube that you screwed off, and which you called the Eye-piece, seems necessary to render this Instrument compleat; but in what Respect it is serviceable to this End, you will please to let me know, *Cleonicus*?

Cleon. I will:———This brings me to consider the second Part, or Effect of this optical Machine, which, you are to know, is intirely of the Microscopic-kind: For the small Image, formed by the great Speculum, is so perfect by Reflection, that it will bear to be magnified a second Time by the small Speculum, and therefore may now be considered as a *Microscopic Object*: Beyond which, if the small Speculum be placed (by Means of the Wire-screw) a little more than its proper focal Distance, then the Rays, which fall on it from the first Image, will not now be reflected *parallel*, as before, but *converging* to a Focus in the Axis of the Telescope produced; for which Purpose, you see it is necessary there should be a Hole in the great Mirrour for those reflected Rays to pass through —In the Point where the Rays are united, there will be a second Image formed from the First, and as much exceeding the First in its Dimensions of Length and Breadth as it exceeds it in Distance from the small Speculum; and therefore you will easily observe, that the Effect of the Telescope in this Part is quite analogous to the compound Microscope, whose Construction I heretofore explained to you.

Euphros. I think, in a general Way, I conceive the Reason of all you say very well; but should be glad if you could familiarize it to me by Experiment.

Cleon. That I can very easily do.——I place the Tube of the Telescope in the Direction of the Sun-beams, and then I have made a little Door to open on the Side of the Tube, by which you may look in and see the Rays reflected, through a large Speculum, to a Focus just at 9 Inches Distance:——The Image of the Sun is there nicely formed, as you will observe, by my holding this small Slip of polished black Ivory there to receive it; which Image, you observe, is perfectly round, and nearly $\frac{1}{10}$ of an Inch in Diameter.

Euphros. This is a very curious Experiment, indeed; the Image of the Sun on the black Ivory is very easy and plain to the Eye,—it appears to be very perfect, indeed, and is, I suppose, now to be considered as a Microscopic Object to the small Speculum.

Cleon. It is so: and you will see a second Image will be formed, by screwing the small Speculum backward,

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at any Distance from it, by Rays reflected through the Hole of the large one, the Eye-piece being taken away:

—Thus, if I hold a Piece of Writing-paper just behind the great Speculum, and keep moving the small Speculum, you at Length see the Image formed very distinct, and large, in Proportion to the first; for the Distances of the two Images from the small Speculum are nearly as 10 to 1; and therefore this secondary Image is nearly 10 Times as large as the first, or about $\frac{9}{10}$ of an Inch in Diameter.—I now place the Paper at the Distance of 18 Inches from the small Speculum, and, as I move the Speculum still farther back, it gives a perfect Image on the Paper in this Position, which is larger than before in Proportion of the increased Distance.—Once more; I place the Paper at the Distance of two Feet from the little Mirrour, and then you see, by removing the small Speculum still farther from the first, how a second Image is formed twice as large as the first in Diameter, and yet very perfect.

Euphros. So very perfect, *Cleonicus*, that I really see the Spots on the Sun's Disk.—Why, this seems to me to be an excellent Way of viewing an Eclipse, the Spots in the Sun, or a Transit, &c. without more ado.

Cleon. It is the most perfect Way, of any, of representing those Phænomena, as they are formed by two Reflections only, and they cannot be shewn by less; and if the great Metal has a large Focus, the Experiment of exhibiting the solar Disk this Way is most delightful, indeed;—as for Instance, suppose it was 3 or 4 Feet focal Distance, the Image of the Sun's Image might be thereby easily made 5 or 6 Inches in Diameter, which will be large enough for all the before mentioned Purposes.

—But to return; this second Image is that which we view by the Eye-glass of the Telescope, in the same Manner as the large Image is viewed by the Eye-glass in the upper Part of the compound Microscope:—From all which it appears, that a reflecting Telescope is a compound Instrument, *consisting of a TELESCOPE and a MICROSCOPE*: and if the Metals are such as are before mentioned, whose focal Distances are as 9 to 1, then, as a Telescope, it will magnify 9 Times, and in the Microscope Part it will magnify 10 Times; therefore,

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upon the Whole, it will magnify 9 Times 10, or 90 Times, and all this in a Length of Tube not greater than 14 Inches.

Euphros. By this compound Power of magnifying I readily discern the Reason, why a reflecting Telescope is so very short, compared with a Refractor of the same Power, and consequently how much more convenient they are for Use, as they are easily applied to a proper Stand or Pedestal, and are capable of a Motion every Way, which not only facilitates its Use, but renders it vastly more pleasant and agreeable.—But one Thing I must remind you of, *Cleonicus*; I remember, some Time ago, I asked you what was the magnifying Power of this Telescope, and I remember you told me, it was about 56 Times, or somewhat more: How, then, does that agree with the magnifying Power you now mention of 90 Times?

Cleon. I will soon satisfy you in that Particular. I have at present supposed, for your more easy Comprehension, that the focal Distance of the small Speculum is only one Inch; but that is found, by Experience, to be too small, or the Power of magnifying too great, to admit of a sufficient Degree of Distinctness and Brightness in viewing common Objects, and therefore it is customary now to make the small Mirrors about an Inch and half focal Distance, and then it will magnify, as a Telescope, six Times, and as a Microscope, about nine Times, and therefore the Power of magnifying will be, upon the Whole, about 54 Times.

Euphros. I apprehend you very clearly, and cannot but admire the wonderful Art employed in the Structure, and the noble Effects of this curious Machine.—But one Thing occurs as a Query, which is this: Since the primary Image in the Telescope is magnified by the small Mirror in the Nature of a common Microscope, pray, *Cleonicus*, would not any small Object, substituted in the Place of that Image, be magnified by this little Mirror in the same Manner, and thereby this Telescope be made to answer the common Use of the compound Microscope?

Cleon. I must compliment you, my *Euphrosyne*, on this happy Thought of your's; for though this Telescope

is now of 100 Years standing, the Use you have now mentioned of it has never been considered till very lately, nor do you find any Author who has given Directions for this Part of the Use of the Telescope:—But, to say the Truth, there is no Microscope can give so perfect a View of an Object as you have this Way; and I can assure you, that this was the Sentiment of a NOBLEMAN of the first Rank (for whom the Muses are now in the deepest Mourning): And whoever has Dexterity enough to apply Objects this Way, will find their Curiosity highly rewarded with the most exquisite Views of Nature's high finished Pieces in Miniature; and that nothing of this Kind in Nature or Art may escape your Notice, I have contrived to make this Method of applying Objects very easy for your Use, *viz.* in the Telescope at large, by a Door opening on the Side against the common Focus of the two Mirrors; where a Pair of Pliers are easily fixed for holding any small Object before the small Speculum in a proper Manner, and then, whether transparent or opaque, it may be viewed by procuring a proper Focus by turning the Screw at the Side.

Euphros. I was just wondering what that Opening, or Door at the Side of the Tube, should mean; but now I see how perfectly it suits the Design:—You'll however oblige me with a View of some small Objects in this Method.

Cleon. With the utmost Pleasure I shall do it, having provided several fit Objects for that Purpose.—In the first Place, the Ends of the Pliers itself, which are placed to hold the Object, will give you full Satisfaction in this Point.—I put the Cover on at the End, to keep all dark about the small Speculum when opaque Objects are designed to be viewed, then turning the Telescope about, so that the Sun-beams may fall on the Side of the Nippers next the said Speculum, you may view the same magnified in a very agreeable Manner by looking through the Instrument in the common Way.

Euphros. It makes a very delicate Object, indeed, and shews wonderfully well the microscopic Power of magnifying in this Instrument:—I cannot but admire the fine Colours which appear; how intense the Blue, and strong the Mazarine!—your Pliers seem, to the naked

Eye, a pretty polished Thing; but in this Instrument it appears very coarse, and furrowed with the Teeth of the File. But now let me view some other Object.

Cleon. The Skin of a Sole-fish is what you have seen in Microscopes, and is what I shall now put in the Plyers for you to view, and form a Judgment of its Appearance in the two different Instruments.—It is now placed in a proper Light: Look at it.

Euphros. I do remember seeing the same Object before; but I must acknowledge I never saw it in that Perfection, and so distinctly, as now:—I cannot see how it is possible for any Thing to exceed the Delicacy of such a microscopic View.—Pray, how do transparent Objects appear?

Cleon. That you will likewise easily find by viewing one single Scale of this Kind in the Plyers:—I have chosen a large one for this Purpose, which you may now observe, the End of the Telescope being now opened for the Sky-light.

Euphros. I view it with great Satisfaction,——and by moving the Telescope a little one Way, and the other, I find that Light which shews it to the best Advantage.——

Cleon. I next present to your View a small Piece of a Leaf anatomized, such a one as you here see divested of its Skin, and all the green Part, which the botanical Anatomists call the *Parenchyma*.

Euphros. Why this Leaf, *Cleonicus*, is one of the finest Objects I ever saw, without being magnified at all; but as its Texture appears so delicate, it certainly requires a magnifying Glass to shew it to its utmost Advantage: A small Piece of that must certainly make a fine microscopic Object.

Cleon. A Piece of an *Aspen-leaf* is now in the Plyers, to gratify your Curiosity.

Euphros. And a great Curiosity, indeed, it is to view it; what wonderful fine Branchery and Ramification through all the Parts, appear!—How amazing are all the Works of Nature, in these artificial Views!

Cleon. These Instances sufficiently shew how excellent a Part of the Telescope has hitherto passed unnoticed by the Public, and how very incurious they have been about the

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the Improvement of so noble an Invention:——But a farther Proof of this we have in the deficient Structure thereof, by all the Opticians hitherto, who, from Father to Son, have gone on in one common Track of limiting our View of all Objects to the Distance of 60, 80, or 100 Feet, according to the different Sizes of the Instrument; so confined and indelicate were their Notions in the Mechanism of this Instrument, that they never considered it as capable of improving the Sight for near Objects;——they left us to the dull Satisfaction of distinguishing a *Fly* from a *Bee*, a *Wasp* from a *Hornet*, or an *Anemone* from a *Jonquil*, &c. by the natural Sight, as if the general Form and Appearance of Objects were all that we were to be solicitous about:——But they who know the Pleasure of the more improved and refined Views even of common Objects, cannot but look upon the usual Structure of our reflecting Telescopes as very imperfect; every Object about us we view with a naked Eye, appears so strangely altered by the Telescope, that you scarce know what you look at. I could engage to shew you many of them, without your being able to guess at the Subject, though ever so well known in a vulgar View.——I shall now try you with an Object you are well acquainted with; but had I said nothing to you, I am well assured you would not have had the least Idea of it, even from the most perfect View;——for this Purpose, turn your Back for a Moment, and be upon Honour not to look upon any Thing but through the Telescope, when I speak.——There it is; tell me what you see.

Euphros. I do not know that I can presently,—it is something vastly large, with a great Elliptic opening at one End, closed in a spherical Form at the other,——over all which are a Number of large deep Holes in proper Arrangement, each one big enough to hold a Bullet;——the Whole seems of a huge cylindric Form; and I do really think, had you not been speaking of this Sort of Deception, I should have formed no Idea of the Thing at all; but as the Case stands, I judge it must very much resemble a *Thimble*, which *Gulliver* might have seen on the Finger of the *Brobdignag* Woman at work with a Needle.

Cleon. The Conceit is very just; for the Appearance would have been much the same as your small thimble thus magnified, by the *Megalascope*: For now this Instrument leaves the Name of a Telescope, which denotes its shewing *distant Objects only*; but when we come to apply it for viewing Objects that are very near, it is called an *ENGYSCOPE*; and on Account of its shewing all the larger Sort of Objects, still much larger than they appear to the naked Eye, it is called a *MEGALASCOPE*.

Euphros. It is on this Account, I suppose, that the smaller Sort of reflecting Telescopes are made with a Drawer, or Tube, to slide out by Means of Teeth and Pinion on the Side.

Cleon. You are right, my *Euphrosyne*, that is the Design of this Construction; for by that Means you may lengthen the Telescope as you hold it in your Hands for viewing any Object in the Room where you sit, or any where about you to the Distance of within 2 or 3 Feet; for let the Object be placed where it will, you need only direct your Telescope to it, and, turning the Screw once or twice round, you will be presented with a new and delightful View of the same.—Here, take this Instrument, and look at any Thing you please about the Room.

Euphros. I will:—And first let me look at the Carpet. How very coarse the Texture and Colours appear! an odd Figure it makes, indeed.—Next, I view the Blind in the Window, which looks as coarse as Wire-lattice, instead of Linen-Cloth.—I now turn the Tube to the Horse-hair Bottom of the Chair; and these I should never have known, had I not first seen them with a naked Eye: They look more like Hurdles of polished Whale-bone.—I next direct it to the silvered Plate of the Barometer, where the Glass-Tube, with the Silver in it, appears as big as your Walking-Cane, and I can plainly see the Index stand at *Fair*.—I shall next remove it to the Fruit-piece, and there I observe the Dish of Nectarines, Grapes, and Filberts, as natural as on the Table itself.—I view my Grandfather's Picture, and it gives Life and Relievo to the Face of the old Gentleman; his Face, his Nose, and Lips, all project in such a Manner, as if coming out of the Canvas.

Cleon. These Objects may afford you a fine Entertainment within Doors; but now throw up the Sash, and view the glorious Scenes of Nature over all the Garden before you: And this I shall propose for your Amusement while I withdraw, at present, to make good an Appointment.

DIALOGUE X.

Of the genuine Construction of REFLECTING TELESCOPES, and also of a new proportional CAMERA OBSCURA.

Cleonicus.

IN our former Conversation on the Subject of reflecting Telescopes, I observed to you, its general Nature in assisting the Sight to discern most perfectly all Kinds of Objects, great or small, remote or near at Hand: I have likewise farther observed, that the Errors of Vision, by Reflection, are incomparably less than those by Refraction, and that therefore the reflecting Telescope is justly esteemed the most perfect of all optical Instruments; and then, with regard to the Construction, I have shewn you how that is to be improved for a more general Application and Use of it. But there is still one Thing remaining, which I think, you ought to be apprized of, and that is, that the reflecting Telescope, in its present Form and Construction, is not made to answer that Character truly, or it is not, properly speaking, a *pure reflecting Telescope*; but its Effect is produced partly by Reflection, and partly by Refraction, and therefore called, by Opticians, a *Catadioptric Telescope*: Whereas, that which produces Vision wholly by Reflection is properly called a *Catoptric Telescope*; of which more at another Time.

Euphros. How do you propose to explain to me the Construction of the reflecting Telescope?

Cleon. I have already shewed you how the Metals and Glasses are placed in this Telescope, which are such as are expressed in this Figure (See Fig. 1.) where A B E H is the Tube of the Telescope, and C P D the Eye-piece

at the End, B E the great Metal with the Hole C D in the Middle, G H is a Stem or Foot on the other End, which supports the little Speculum xy ; in the Eye-piece, W X is the first Glass, or that which is next to the great Metal: Y Z in the second Glass, or that next the Eye at P.

Euphros. This I know is the Disposition of the Glasses in the Telescope I have seen; but now, how the Image is formed by Reflection and Refraction both, you will please to explain.

Cleon. I will: In order to which, let $a c$ and $b d$ represent two Rays proceeding from a Point, of a very distant Object, placed in the Axis of the Telescope; they will, after Reflection from the Points c, d , in the large Metal, be converged to a Point e in the said Axis: And, in like Manner, Rays proceeding from all other Points of that Object will, by the great Speculum, be converged to so many other Points at the Distance $Q e$, where they will all together form the Image of that Object I M.

Euphros. This I well remember you shewed me, in explaining the Nature of concave Mirrors of Glass; and moreover, that the Position of the Image I M is contrary to that of the Object, or inverted. Lastly, I observed that this Image I M is formed wholly by reflected Light: —But, pray, *Cleonicus*, let me ask you one Question; how comes it to pass that the Image is perfect and entire, when there is so large a Hole in the Center or Middle of the Speculum? I should have thought that Hole would have occasioned some Deficiency in the middle Part of the Image.

Cleon. Not at all, my *Euphrosyne*; for you will easily perceive that any small Part of the Speculum alone may be considered as an entire Speculum of itself, and will form the Image, or Appearance of any Object, as well as the Whole, only the Picture will be less luminous in Proportion as the Surface is less; and this is the Reason why, when a Speculum is broke into ever so many Pieces, every Piece, great or small, forms the same Image of a given Object, in every respect but that of Brightness; and therefore the Hole in the Middle of the Metal avails no more than it would do to stick a large black Patch any where on the Surface of an entire concave

Glass,

Glass, which you would find would make no Difference at all in the Appearance of an Image, or perspective Picture, formed thereby.

Euphros. I apprehend you very well, and shall interrupt you no farther in this Matter.—What do you next observe in the Structure of this Instrument?

Cleon. You are to take Notice, that the Point f is the solar Focus of the small Speculum xy , and therefore by moving this Speculum to the Distance Ge , greater than its focal Distance Gf , the Rays ey and ex , diverging from the middle Point e of the Image, will, after Reflection at y, x , be made to converge to some distant Point in the Axis at k ; but, in their Passage at no , are intercepted by the first Glass WX , and by it are refracted to a Point nearer to the Glass at K , in the Axis of the Tube; also, two other Rays, IG and MG , proceeding from two extreme Parts of the Image IM to the Center G of the small Speculum, are from thence mutually and alternately reflected on contrary Sides in the same Direction towards the distant Points MI ; but in their Way are intercepted by the first Eye-glass in the Points WX , and from thence refracted to the Points RS ; and therefore the second Image is RKS , and is formed partly by Reflection from the little Metal xy , and partly by Refraction through the Glass WX : And hence it is, that the Instrument, in this Form, partakes of the Nature of a reflecting and of a refracting Telescope, and is of a middle Kind between both.

Euphros. And therefore, of Course, it must likewise partake of the Advantages and Disadvantages of both those Sorts of Telescopes: The principal Imperfection, I suppose, is, that arising from Refraction through the Glass WX :

Cleon. You observe rightly, my *Euphrosyne*, that is an Objection that a Catadioptric Telescope is liable to; the second Image cannot be formed without a *colorific* Refraction, and therefore cannot be so perfect as one that is formed wholly by reflected Light*. At present, I have another

* *N. B.* We have thought necessary to illustrate the Doctrine of reflecting Telescopes by Figure I. of Plate 48, as it will greatly

another optical Instrument to describe, which I fancy will give you equal Pleasure with many of the foregoing, especially as it contains, in a small Compass, a general Praxis of optical Experiments: The Instrument I mean is a new proportional *Camera Obscura*.

Euphros. It is a pretty Instrument, I allow; but how does this differ from the common *Camera Obscura*?

Cleon. In three Respects: First, in the Form; but this is the least of all material.—Secondly, it forms an Image in any assignable Proportion to the Object, in all Degrees below Equality.—Thirdly, *Wilson's* Microscope is adapted to it, for exhibiting a large Image of any very small Object.

Euphros. By what you have said, *Cleonicus*, I suppose the Use of this *Camera* is principally for *Drawing*.

Cleon. That is the chief Design of it: As the Arts of Design and Drawing are very innocent, instructive, and useful, they ought to be considered as a Part of the polite Education of every young Lady and Gentleman of Genius; and therefore all Helps should be furnished for rendering them easy in Practice: And as every Art proceeds at first from Imitation, so do those (more especially which are relative to Drawing and Painting, and the better the Originals are, the more exact and exquisite will be the Improvements that are acquired by copying of them; and it is well known, that Nature's Drawings, Perspective, and Painting, are in themselves most perfect, and therefore ought to be proposed in the first Place for Imitation.

greatly assist the Imagination in representing the Course of the Rays of Light, by right Lines drawn in the Manner as the Rays are reflected by the Speculums, and refracted through the Glasses, as we could not so well give a Representation of the Sun-beams passing through this Instrument in a darkened Room, as we did for the several Sorts of refracting Telescopes in Plate 47; also in Figure II. we have shewn how the several Pencils of Rays proceeding from the Points of a distant Object *Q B* are refracted by the Glasses of a common Telescope, viz, the Object-glass *x z*, and the three Eye-glasses *a b, p q, c i*, so as to produce distinct Vision upon the optic Nerve in the Eye in the inverted Picture *r s p*; by observing the Course of those Rays, or Lines, the Reader will have a better Idea of what was delivered on this Subject in a former Dialogue.

Fig. 1.

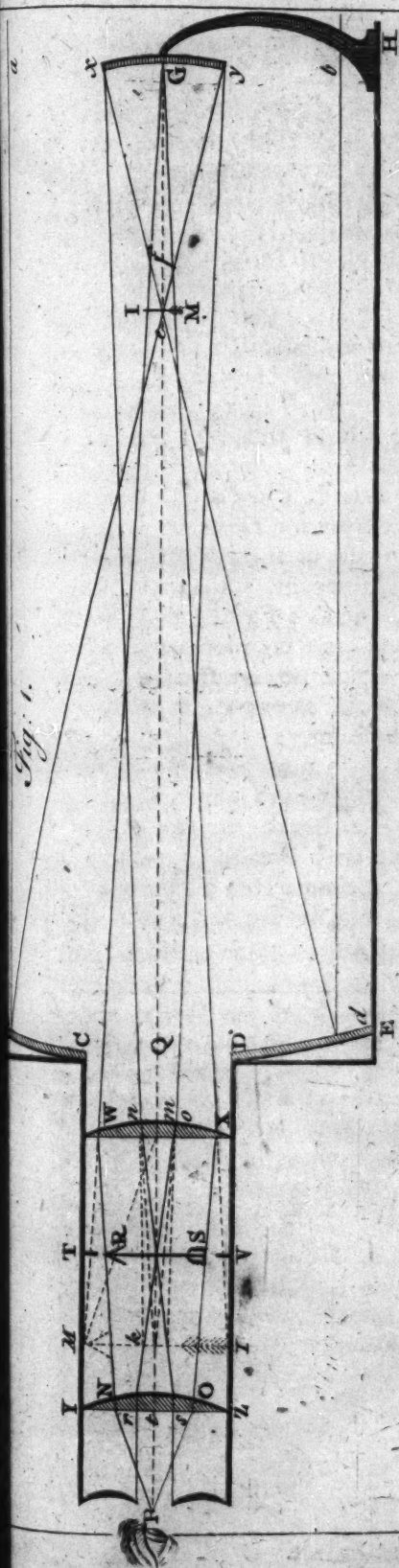
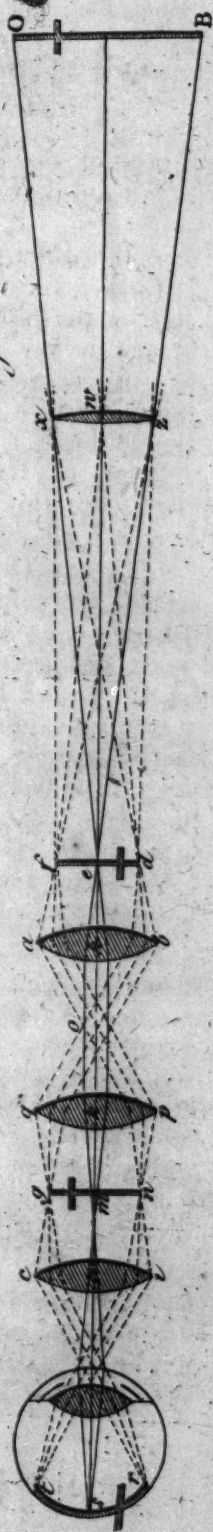


Fig. 2.





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Imitation. They who do not draw, or design, from Nature, in effect do nothing, as neither Spirit nor Sublimity can be found in any other Compositions: But in order to qualify a Person to copy Nature with Art and Judgment, he ought first to be acquainted with the Nature and Rules of Perspective; for Nature, it is well known, is all Perspective to the Eye. If we take a Survey of Fields, Gardens, distant Towns, &c. they all appear to the Eye as if represented on a transparent Plain, placed perpendicular, to the Horizon at a small Distance from you.

Euphros. If then I take you right, *Cleonicus*, you mean, as yonder Fields and Meadows appear on the Glasses of this Sash-window to my Eye, viewing them here in the Room?

Cleon. Exactly in the same Manner, my *Euphrosyne*,—all the Ground beyond the Window, which you see, rises on the Glass plain, and, by Degrees, the Parts lessen to the View as they are more remote, till they become very indistinct, and gradually disappear in the most distant Part which you see, and is called the perspective Horizon on the Window.

Euphros. In what you have now said, you seem to have described a visual Landscape on the Window.

Cleon. The common Landscape is only the same Thing in Oil-colours on the Canvas, if executed by the Rules of Art.—I only take this Opportunity to convince you, that all picturesque Representations of Nature are strictly limited by perspective Rules; and they who do not therefore observe them in their Drawings, and Designs, must never expect any Praise for their Performances.—Now as all those Imitations of Nature are a Sort of Miniature-painting (for the largest Landscape is only a perspective Representation of a large Field of View in a small Compass) therefore, in order to facilitate such a Practice, Art supplies manifold Helps to that End.—A Person the most skilful in Perspective, and in the Art of Designing succeeds but ill in Landscape-painting, without long Practice in the common Way, or otherwise by having Recourse to their Assistance.—What I mean regards that Variety of artificial Pictures and Landscapes that are made by different Sorts of Glasses; for you very well know,

know, that no polished Mirrour can be exposed to a Building, or distant View, but there immediately results an extemporaneous Picture of the same in true Perspective, if the Glass be of a proper Size.

Euphros. This I have oftentimes, with the highest Pleasure, observed, and I think nothing can compare with the Beauty and Perfection of those Landscapes that I have seen formed by large convex Speculums.—Those Pictures which you shewed me in the darkened Room, some Time ago, are of the same Kind, but inverted.—In short, I often amuse myself with the picturesque Appearance of Objects, by Reflection of almost every Kind of Glass that comes in my Way.

Cleon. As those Glasses give so just and artificial a Representation of any particular View of Nature, they have been much used in those Sorts of Instruments called portable *Camera Obscuras*, because in them the Artist can easily observe the true Disposition of all the Parts of the Piece he intends to draw, the Contours or Out-lines of the Figures, the perspective Diminution, the *Claroscuro*, or the Light and Shades, with every other Circumstance necessary to be observed in forming the perfect Picture.—But after all, this Instrument is not perfect in a principal Particular which I mentioned to you before, and that is, the Artist, by a common *Camera*, cannot draw any particular Building, or other Object, in a given Proportion of Magnitude, as is often required; and therefore I have contrived this, which you here see, to supply that Defect.

Euphros. By what Means is this effected? I should be glad to find myself capable of understanding the Reason of it.

Cleon. That I will endeavour to shew you by Experiment.—When Objects are at a very great Distance, or so remote, that the focal Distance of the Glass bears no Comparison to their Distance, then the Image or Pictures of those Objects are formed in the Focus of the Glass, and bear no sensible Proportion of Magnitude to the Objects:—But in Case of Objects near at Hand, their Pictures become larger, and will bear a sensible Comparison with the Object, viz. the Proportion of their Distances from the Glass, all which I have formerly observed to you, and shewed you by Experiment.

Euphros. I remember you did; and I can easily understand, that as the Object approaches the convex Lens, the Image will recede from it; for as the Distance of the former decreases, so that of the latter will increase, and the Size of the Image will also increase along with it: And according to this Doctrine I can easily conclude, that the Distances of the Object and the Image may at Length become equal, and that consequently they themselves will become equal also; but what the Ratio of these Distances is, for any given Proportion of the Object to the Image, I presume the Learned only can know.

Cleon. I can easily supply you with a Rule for determining the same; but as it will be different for every different Sort of Glafs, I shall not pretend to trouble you with it, having put it in your Power, by Means of this Instrument, to form the Image for any Object equal in Magnitude to the Object itself, or in any Proportion less, at Pleasure, from one to a hundred Times.—One Thing, however, I think is a Matter of some Curiosity, and therefore proper you should know, *viz.* that when an Image and Object are equal, their Distance from the Glafs being also equal, will be just double the focal Distance of the Glafs.—Thus, supposing the focal Distance of a Glafs was nine Feet in a scioptric Ball and Socket, placed in the Window-shut of a dark Room, then if you were to place yourself before the Window, at the Distance of eighteen Feet, a Person in the Room will see your Face of the same Magnitude as it really is, on the Screen at the Distance of eighteen Feet from the Window.—In the same Manner, if the Glafs were but ten Inches focal Distance, any Object placed before it, at the Distance of twenty Inches, would have the Image formed on the Screen at the Distance of twenty Inches from the Window; and this is the Case of one of these Glasses which belongs to this proportional *Camera Obscura*, which being screwed on in the Front of the Box, and being then drawn out to the Distance of twenty Inches, marked on a proper Scale, whatever Object is placed before this Glafs, at the Distance of twenty Inches, will have its Image formed on the Glafs of an equal Size with the Object.

Euphros. Let me try that Experiment with my Snuff-box, which I will place in an advantageous Light:—Now let me draw out the Glass to the Distance of 20 Inches,—and then I move it forward and backward till I see the Image perfect;—and then, as you observe, I see the white enamelled Lid, and the whole Box just of an equal Size.

Cleon. Then there let it rest, till I measure the Distance with this Rule,—which, you observe, is just 20 Inches from the Glass to the Box, the same as the Distance of the Image.—And hence you see how easy it is to draw any Object, not larger than the Glass, of an equal Bulk.

Euphros. On the Right-hand Part of the Copper-plate Paper, on the Drawer, is a double Row of Figures appositely placed by the Scale of Inches; pray, what do they denote?

Cleon. They shew the Proportion of Magnitude between the Object and the Image when formed on the Glass, when the Drawer is moved or set to any of those particular Numbers: Thus, for Instance, if I move it to the Number 15 or 10, then is the Glass 16 Inches and $\frac{6}{10}$ from the End; and whenever an Image in that Situation is formed in the Glass, its Size, or Dimension of Length and Breadth, will be to those of the Object as 10 to 15.

Euphros. After the same Manner, I suppose, if I move the Drawer to 15 Inches on the Scale, the Outlines of the Image then formed on the Glass will be to those of the Object in Proportion as 10 to 20, or just half as big.

Cleon. That is the very Thing; you there represent the Object of half its natural linear Dimensions.

Euphros. But I observe in that Scale, the Proportions go no farther than of 30 to 10.

Cleon. It is true; when the Drawer is moved quite home to the Numbers you mention, the Length and Breadth of every Image on the Glass is just $\frac{1}{3}$ Part of that of the Object,—and this is as far as we can conveniently go with a Glass of 10 Inches focal Distance:—But now, if we take that out, and place in another Glass of 15 Inches focal Distance, then with that we can form an Image in any Proportion less than the Object, from that of $\frac{1}{3}$ to $\frac{1}{10}$ Part.

Euphros. For this I observe you have a Scale on the Left-hand Side of the Paper,—and that when the Drawer is moved quite out to 20 Inches, the Proportion is then as 1 to 3.—If I move it to 18 Inches, the Proportion is that of 1 to 5.—Again, 16 Inches and $\frac{1}{2}$ gives the Proportion of 1 to 10; and thus, I observe, by moving it to the several Numbers successively on this and the other Scale, I can form an Image in any assigned Proportion less than the Object, by using the proper Glasses, which, on many Occasions, must be very convenient.

Cleon. The young Artist will always find Occasion for drawing of Objects less than the Life, and oftentimes of a given Size, which he may do by this *Camera* as well as by any other, and have the Pleasure of seeing at the same Time the Proportion between the Image and the Object: But of this I have said enough to give you a clear Idea of the Nature and Design of the Instrument, and shall now leave it with you to render the Use of it more familiar, by Practice, and to make it a Part of your Amusement at leisure Hours*.

D I A L O G U E XI.

Concerning the TRANSIT of the Planet VENUS, and its EGRESS from the SOLAR DISK, on June the 6th, 1761, in the Morning; together with some CALCULATIONS relative to the ELEMENTS of her THEORY. Also of the SATELLITE supposed to attend her.

Euphrosyne.

AT Length, the long expected Morning came, and the universal Phenomenon viewed to greater Per-

* I thought it not necessary here to say any Thing of the Use of the *Solar Microscope*, since that will not be difficult to any one acquainted with that Instrument already so fully described. This new portable *Camera Obscura* is shewn in Fig. 1. of Plate I.

fection,

fection, than could be expected from the Weather for many preceding Days.——Well, I cannot but say, I viewed the glorious Spectacle with more exquisite Pleasure and Satisfaction, than ever I beheld any other Object in the whole Circle of the Creation; and to other admiring Mortals, as well as myself, I make no Doubt but she appeared more desirable and eligible in her sable Dress, than when arrayed with all the Splendor of the Morning.——*Phosphorus* and *Hesperus* are indeed most glorious Contrasts of what she appeared this Day upon the Sun:——Divested of all her usual Radiance, she shewed herself in the natural Simplicity of a dark, or opaque Planet,———so large, so black, so perfectly round, and uniform in her Motion, that she answered perfectly to all the Ideas of Expectations that had been formed from every Prediction of this great Event.——And since I have had the Pleasure of observing this Phænomenon, I must desire you to give me some Account of the same, and how you apply it to the Uses you formerly mentioned to me.

Cleon. The Morning, upon the Whole, proved very favourable; the rising Sun would have been an acceptable Sight; but this was not permitted to us at *London*, though, in many Parts of *England*, they had the Satisfaction of viewing it the whole Time.——However, we had, as if for the Purpose, a clear Sky, for observing the critical Moment, which was that of her Egress, or Emerision from the Sun's Disk: Which gave us a fair Opportunity of observing, to nearly a Second of Time, the Moment when she touched the Limb of the Sun internally and externally, and thereby to determine the Space which she passed in her visible Path during the Time of her Egress: Which Space, were it accurately ascertained, would be of the greatest Consequence for settling the principal *Elements* in the *THEORY* of this Planet's Motions.

Euphros. I do not then wonder that you and several other Gentlemen were so very attentive to that Particular, and that you were so very busy with your Watches in observing those Moments of Time.——But were you sure that your Watches were perfectly right, or that they shewed the Time of those Incidents truly?

Cleon. They were adjusted by Regulators the Night before; but whether they were exact as to what the Astronomers call the mean Time, was not so much the Question here; the principal Thing, in regard to the Time, was the Division of it into *Seconds*; for by this Means we could observe, nearly to a *Second* of Time, the Moment that the Planet touched the Sun's Disk internally, and also the external Contact, within a few Seconds. Now, if you remember, I told you that *Venus* at this Time very accurately described *four Minutes* of a Degree in an *Hour*, or 60 Minutes of Time, and therefore one Minute, or 60 Seconds of Motion in each Quarter of an Hour, or 15 Minutes of Time; which is at the Rate of four Seconds of a Degree for a Minute, that is, 4" for every Second of Time; from whence you must observe, that a few Seconds of Time in the Duration of the Emersion will produce no sensible Error in the Space described by the Planet in that Time.

Euphros. I farther observe, that you were not a little anxious about the Size or Dimensions of the planetary Spot, and that you took Notice in particular how far it fell short of the Number of Seconds which Dr. *Halley* gave it in his Dissertation.

Cleon. This is another Point of no small Importance towards perfecting the Theory of this Planet, as without it no great Use could be made in Calculations depending upon the exact Time, or Space described in the Emersion, as I shall illustrate to you more particularly in a very large Diagram by-and-by, which shall be a Representation of the Sun's Disk 8 Feet in Diameter, and that of the Planet 3 Inches, by which every Thing relating to those Particulars will be evident by Inspection.—Dr. *Halley* made the Diameter of this Planet 75", whereas she appeared by our Measurement not to be 60". I had prepared an Instrument for measuring the Diameter of the Planet with the greatest Exactness, but found it was impossible to apply it in a public Company.

Euphros. By these Observations you can ascertain the Ratio of the Diameter of the Planet to that of the Sun?

Cleon. Yes, pretty nicely; for Dr. *Halley* gives 31' 51" or 951" for the Diameter of the Sun: But by measuring it very accurately by the Micrometer, a few Days after

the Transit, I could not make it less than $32'$ or $960''$; and supposing that of the Planet was nearly one Minute, their apparent Diameters were to each other as 32 to 1.—By this Experiment of the Transit, we find how much more accurately the Planets are to be measured when divested of their Lustre or Radiance.

Euphros. I remember you told me heretofore, that this Planet was near as big as the Earth; but since you have now found her Diameter less than was usually estimated, I suppose she will shrink to a less Bulk, and we shall now have a greater Superiority over that Planet in regard to Magnitude than was heretofore supposed.

Cleon. Yes, she now dwindles very much indeed; the Magnitudes of all Bodies, viewed at the same Distance, being in Proportion to the Cubes of the Diameters: Now the Cube of 75 to that of 60, is as 412 to 216, and therefore the Planet is, by this Observation, reduced to nearly one half of its former supposed Magnitude, or to little more than half that of the Earth, and must now be reckoned the least of all in the Heavens but one, viz. *Mercury*; whereas, heretofore the Planet *Mars* was thought to be so.—However, her Magnitude is so very considerable, that, in regard to her Vicinity to the Sun, she makes the most resplendent Appearance, and has always been regarded as the most beautiful of all the planetary System, insomuch, that the GODDESS of BEAUTY herself was honoured with her Name.

Euphros. This Phænomenon of the Transit of *Venus* is looked upon as a great Curiosity, I suppose, on Account of its happening so very rarely; but what may be the natural Reason, or Cause of this, I should be glad to know, *Cleonicus.*

Cleon. You will easily perceive the Reason of it, when you recollect what I have said concerning the Limits of solar and lunar Eclipses, and especially if, with that, we consider the Smallness of *Venus's* Diameter compared to that of the Sun, and the long Intervals between the Conjunctions of this Planet which produce a Transit; and, lastly, the great Proportion which the Velocity of the Earth bears to that of *Venus* in her Orbit.—But to be more particular: You are to consider, (1.) That if *Venus* was to move in an Orbit in the Plane of the Ecliptic,

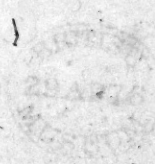
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Ecliptic, she would then appear to pass over the Face of the Sun in every inferior Conjunction, which would be in the Space of one Year and 8 Months nearly. (2.) But the Orbit of *Venus* does really make an Angle with the Ecliptic of nearly three Degrees and a half, and therefore the Orb of the Planet cannot possibly be seen on the Sun, unless she happens to be within a certain Distance of the Node at those Conjunctions; and though the Inclination of the Planes of the Ecliptic and her Orbit be so small, yet, on the Account of the Smallness of her Diameter, the ecliptic Limit on either Side the Node would be somewhat more than four Degrees, if she were to be viewed at those Conjunctions from the Earth at rest. (3.) But the Earth and Planet being both in Motion, and since *Venus* moves at the Rate of four Minutes in an Hour, and the Earth $2' 28''$ per Hour, their Velocities will be in Proportion as 240 to 148, the Difference of which is $92''$: And on this Account the angular Motion of *Venus* from the Ecliptic (as viewed from the Earth in Motion) will be increased in the Proportion of 240 to 92; and therefore will amount to near eight Degrees and a Half: Hence, as her visible Path makes so great an Angle with the Ecliptic, the Limits of the Transit will be greatly contracted, or will not amount to more than one Degree and three Quarters on each Side the Node, instead of 4 Degrees and $\frac{1}{2}$, as before. From hence it will appear, that *Venus* and the Sun must be very near the Node at the inferior Conjunction, for any Transit to happen: And of Course, since (4thly) the Intervals of these Conjunctions are so great, the Chance of the Sun's being within the Transit-limit when *Venus* comes round to the Node, is consequently very great also; and therefore it will appear, upon all these Accounts, that *Venus* can be very seldom seen upon the Face of the Sun. But I shall take Occasion to illustrate these Things, by a large Diagram, at another Opportunity.

Euphros. You will by that much oblige me, though I can very easily apprehend the general Reason of all that you have now said, from the astronomical Principles which I have heretofore received from your Instructions.

—— But now, *Cleanicus*, let me know what kind of

The BEGINNING & END of the EGRESS of VENUS from the SUN'S DISC.

Plate XIX.

Uses you intend to make of your Observation on the Transit.

Cleon. As the Beginning of the Transit could not be observed in *England*, the great or general Design, viz. of making a proper Estimation of the *Parallax of the Sun*, could not be pretended to, this must be left to a Comparison of many Observations that are made in very different and distant Places, where the Parallaxes of Longitude and Latitude favour that Design in the greatest Degree; and this will be a Work of some Time. But when all the Observations that have been made here, with proper Degrees of Accuracy, are compared, the Position of *Venus's* visible Path upon the Sun will be nearly ascertained: Also her visible Latitude at the Conjunction, and Place of the Node, will be deducible from thence, which are Points of the utmost Consideration to be settled in the Theory of this Planet's Motion. I have prepared a Diagram that may serve to give you some Idea of what I mean relating to these Subjects: That Part of the Sun on which the Planet appeared to us, let us suppose to be represented by *HLIMN**, the Center of the Sun *S*, *MH* a Part of the Eclipse, and *CD* the true Path of the Planet as viewed from the Center of the Earth, parallel to which is the Line *SK*, making an Angle with the Ecliptic *HSK* of 8 Degrees and 28 Minutes, the Angle of *Venus's* apparent Motion, which I just now mentioned unto you; and let *APVB* represent the Curve-line Path of *Venus's* visible Motion on the Sun's Disk.

Euphros. I should be glad, *Cleonicus*, if you would tell me why the visible Path is not a straight Line, as well as the true Path *CD*.

Cleon. The Reason of that you will understand as soon as you consider, that the Difference between the true and apparent Place of the Planet is occasioned by its Parallax, as I have formerly shewn you, and which Parallax, depresses the Planet below its true Place, and more so in Proportion as the Planet is farther from the Zenith, or nearer to the Horizon; and consequently when the Planet

Planet appeared in the Horizon at A at Sun-rising, it was then depressed below the true Path at C by the whole Quantity of the horizontal Parallax, which is more than $40''$: But as the Planet advanced on the solar Disk, and the Sun grew higher above the Horizon, the Quantity of the Parallax in Altitude did constantly decrease, and therefore the Planet's apparent Distance from its true Path must be always decreasing likewise as it passes from A to D, and that in such a Manner as to occasion the visible Path to be in some Degree a Curve-line; so that when it came to touch the Sun's Limb internally at (a) when the Distance of the Sun from the Zenith was about 41° , then the Parallax in Altitude was but about $30''$, and therefore the apparent Distance from the true Path at the Egrefs was more than one fourth Part less than at Sun-rising.

Euphros. You have satisfied me in this Particular; and I think in your Diagram the Planet makes the very same Appearance as she did on the real Disk of the Sun.

Cleon. It is drawn pretty nearly in the same Proportion as you then saw it on the Paste-board Screen; you observe, the Planet is here placed so as to touch the Sun's Limb internally and externally at (a) and (c).

Euphros. This, I presume, I can conjecture the Reason of; for I well remember, you were often speaking about the Method of determining the Position of *Venus's* Orbit, from an Observation of the Time in which she passed from (a) to (c), or the Time of the entire Egrefs or Emerfion from the solar Disk.

Cleon. It is true, my *Euphrosyne*, this was what induced me to be more than usually curious, and anxious in nicely observing the Moment of Time for each of the two Contacts; because that Time, if it could be accurately defined, would give the Length of the Space or Line (a c), then if we draw the Line S a and S c, there will be formed an oblique Triangle a S c, in which all the three Sides are known, supposing the Diameter of the Sun and Planet to be exactly determined by a Micro-meter. If then we continue the Line c a to F, where it meets the Perpendicular S F, from the Sun's Center, the Distance of the Point F from a and c will be known, from Principles of plain Trigonometry, therefore also

the Distance of Fb , which is just half the Length of the Chord, or parallatic Path of *Venus* upon the Sun: Hence, therefore, the Time of describing that Chord would be known; also from hence the visible Conjunction $S P$ will be likewise known, and also the Point of the Ecliptic to which the Line $B F$ tends, or Place of the Node will likewise become known: And when, from Observations made abroad, it shall be known what the true Quantity of *Venus's* horizontal Parallax is, then $E F$ will be also known, which is the Difference of the true Path from the visible One, and therefore its Position will be known also. ——— But it must be confessed, that Matters of such great Nicety and Importance ought not to be trusted to, or made to depend upon one single Observation, but ought to be deduced from all that are made of the Planet while it was seen on the Disk, but principally those which relate to the Time of the Egress, and the perpendicular Distance of the Planet from the Limb of the Sun, at different Instants of Time, during the Transit. ——— Therefore, at present, we must be satisfied to have only a general Notion of these Matters, and must postpone the farther Consideration of them to a future Opportunity, that may furnish us with fresh Materials for prosecuting this Subject in a more extensive Degree.

Euphros. But what is your Opinion, *Cleonicus*, concerning a Satellite's attending this Planet, which has been of late so much the Subject of Conversation, and which some of the Gentlemen present apprehended they saw on the solar Disk?

Cleon. A Man's Opinion in such Cases avails little or nothing; but this I know, that what the Gentlemen took for a Satellite in the Sun was only a solar Spot, and it is certain that what was published in the common News-papers was the same Kind of Mistake; for the Satellite having a similar Appearance with that of the Planet, viz. perfectly black and circular, and withal so large as to equal the fourth Part of the Planet's Diameter, must necessarily have been very easily seen on the Sun's Disk, had any such Thing been there; and farther, as the Distance of this Satellite is supposed not to exceed 50 Semi-diameters of its Primary, it is very certain, as it has been

been observed to move in a Circle directly before the Eye, it must necessarily have been observed on the Face of the Sun, unless it happened to be in the lower or southern Part of its Orbit.——From the Accounts of Mr. *Cassini*, Mr. *Short*, and now of these *French* Philosophers, it is very certain there is something that must have appeared about the Planet in their Telescopes; but whether it be a Satellite of the same Nature and Kind with those which belong to the *Earth*, *Jupiter*, and *Saturn*, is a very great Question, because of the unusual Position of its Orbit, and of its very seldom and precarious Appearance. Were it only an opaque Body, like another common Satellite, it would, like them, appear at all Times in a uniform Manner, more or less enlightened, but generally in the Form of a Crescent, like the primary Planet itself; and as *Venus* is so near to the *Earth*, at her inferior Conjunctions especially, it would be impossible not to have a frequent View of a common Satellite that attended her.——You must, therefore, in regard to this Phenomenon, wait for farther Information to arise from repeated and accurate Observations, and, according to those which have been already made, the Time for settling the Theory of this Satellite seems not to be very near: But if ever it comes to pass, it will conduce not a little to the Advancement of Astronomy and natural Philosophy; for, in the first Place, the Astronomy of the Secondary Planets will then receive its last Perfection, for no Satellite is ever to be expected about *Mars* or *Mercury*. And, Secondly, the Power of Gravity in the Planet *Venus* can then be known and compared with that in the *Sun*, *Saturn*, *Jupiter*, and the *Earth*; for the Quantities of Matter in any two Planets are in a certain Ratio of the periodical Times and Distances of the Satellites which revolve about them, and consequently the Forces of Gravity which are proportioned thereto; and that this Planet, in her lower Conjunction, approaches so near the *Earth*, her Force of Gravity and its Influence on the Motions of the *Earth* and *Moon* may be looked upon as not very inconsiderable, and consequently the Share it has with the perturbing Forces of the other Planets and Comets, introducing Irregularities in the Motions of the *Earth* and the *Moon*, may then be

estimated, and consequently the Theory of these Planets (the most considerable in the System) will be thereby greatly improved.

Euphros. Since such great Events depend on a Discovery of a Satellite about *Venus*, it is not to be feared, I suppose, that the Vigilance of Astronomers will one Day or other put that Matter out of all Doubt, and satisfy Posterity whether it be a real Satellite, or a mere *Ignis Fatuus* that now amuses them and perplexes their Curiosity.——But what is this Preparation, or Apparatus of Globes, Orreries, and other Things which I see here upon the Table?

Cleon. These, my *Euphrosyne*, are intended to entertain you with an *artificial Transit*, and not only that, but likewise to explain, at the same Time, the *Rationale* of so curious a Phænomenon as far as I can do it by Instruments——It is a great Satisfaction and Pleasure which the real Transit has afforded so many thousand *Virtuosi*, but, I think, that is not enough for you; for it has ever been my chiefest Care to enliven your Ideas with the *Rationale* of them, and then you have the highest Entertainment that the Nature of Things affords.——You here observe three Instruments placed on a Right-line, by each other, on the Table; that in the Middle, you will recollect, is the artificial *horological* Globe which I made use of to explain the Nature and Reason of Eclipses.

Euphros. I see it is the very same Globe; but the Apparatus is not the same as you then made use of.

Cleon. It was necessary here to make an Alteration in that Respect; for now this Globe is to be connected with the Orrery, which you see on the right-hand Side, and with the Transit Instrument on the Left.

Euphros. But the Orrery is the same which you formerly used in explaining to me the solar System, at least, so far as I can perceive.

Cleon. There is one material Difference, my *Euphrosyne*, in the Structure of those Orreries;——that which I then used, moved with Clock-work; this, which you here see, is put in Motion only with a Winch, when used by itself, by which Means it is easily connected with, and put in Motion by the Globe, by Means of that String which you see go round the Pulley.

Euphros. The same String, or silken Cord, I observe goes on the other Side to the Transit Instrument, as you call it, which, as it consists of a Board with a black Ground and a large silvered circular Plate in the Middle, is, I suppose, intended to represent the Sun in the dark Field of View in the Telescope; I likewise see the silken Line go over that Part of the silvered Plate which *Venus* traversed on the real Sun; and so, I presume, represents the visible Path of *Venus* on the solar Disk. But where is the Planet itself, *Cleonicus*?

Cleon. That you will see by-and-by:—You will first take Notice that, in general, the Motion of the *Earth* will necessarily give Motion to the Orrery on one Hand, and to the Line over the artificial Sun on the other; and that, by this Means, the Planet *Venus* will appear in the periodical Revolutions about the Sun on one Side, and exhibit the natural Cause of her retrograde Motion and Conjunction with the Sun, in the Orrery, at the same Time that she is seen to pass over the solar Disk, in the Transit Instrument on the other Side.—And, lastly, the Motion of the *Earth*, the relative Positions of its Inhabitants, and the several Moments of Time for the respective Phases and Circumstances of the Transit, are all shewn by the Globe.

Euphros. But if you intend I should have a clear and distinct Idea of the complex Effect of this Apparatus, you must be particular in explaining what I am to see, and have a direct Regard to, in each particular Part of it.

Cleon. This I will do: And, first, with respect to the Orrery, I will place all the Planets in such Parts of the Ecliptic, as they appeared in on the first Day of *January*, or the Beginning of the present Year, and, when the Machinery is in Motion, you will have a particular Regard to the Motions and Position of *Venus* and the *Earth*; and, on the 6th of *June* on the Plate of the Orrery, the Planet will come exactly between the *Earth* and the *Sun*, and from thence the Manner how the real Transit is occasioned will be easily conceived.

Euphros. That I shall attend to; but what am I to observe in the *Earth*?

Cleon. The following Things; (1.) In order to adjust the *Earth* to its proper Position for that Time, I bring the Index,

Index, at one End, to point to the 6th of *June*, which will bring the North-pole of the Earth to its proper Situation in the enlightened Hemisphere. (2.) As the *Sun* is then over the middle Point of that Hemisphere, I turn the Globe till the Meridian of *London* passes through the *Sun* in that Point, and there holding it fast, I turn the Dial-plate till the other End of the Index points to XII at Noon. (3.) Then I revolve the Globe backward, 'till the Index points to about a Quarter after II in the Morning, which was nearly the Time of the Beginning of the Transit, at *London*. (4.) Then the Mland of *Great Britain*, and all other Places have their respective Situations for that Phase of the Transit.

Euphros. I suppose you mean that any particular Place, as it is situate in the light or dark Hemisphere, will be able to view, or not to view the Beginning of the Transit. Thus, for Instance, *London* appears at that Time far within the darkened Surface of the Globe, and *St. Helena* still more remote from the Circle of Illumination, whilst, on the other Hand, I see *Bencoolen* in *Sumatra*, and all the Eastern Part of the Globe, in the illumined Hemisphere, viewing the Planet entering the solar Disk, in various Altitudes above the Horizon.

Cleon. If now, in the last Place, you cast your Eye on the black Ground of the upright Board, you may observe, on the Left-hand Side of the silvered *Sun*, a large black round Patch just ready to enter, and shew itself on the Limb of the Solar Orb.

Euphros. Yes; I see it now you direct my Eye; but before it was so much of the Colour of the Board, or rather no Colour at all, that I did not perceive it at this Distance. — By the brass Screws on the Side of the Board, I suppose you can adjust the Path of *Venus* to any Part of the *Sun*, or so as to cut the Ecliptic in any given Point, as the Position of the Nodes require; and the Limb of the *Sun* being divided into Degrees, the Quantity of the Arch at the Ingress and Egress of the Planet from the Ecliptic Diameter of the *Sun* is easily represented.

Cleon. You seem now to have a just Apprehension of the Uses and Designs of the several Parts; it remains, therefore, now to put the whole in Motion, which, as

it is very slow, will afford you an Opportunity of viewing very minutely all the Peculiarities of the Transit in each separate Machine.——I wind up the Spring, and now observe the diurnal Motion of the Earth,——the planetary Motions about the Sun,——and the artificial Planet or Patch just entering the eastern Limb of his Disk.

Euphros. The several Phænomena you mention in the respective Machines are now very obvious:——In the Orrery, I see all the Planets moving in their proper Orbits from the Beginning of the Year; and though the *Earth* be at that Time before the Planet *Venus*, yet, as that Planet follows with a quicker Motion, she is every Moment advancing nearer and nearer to a Conjunction, till at Length I perceive them both in a right Line with the *Sun*, on the 6th Day of *June*, on which Account, as she is then so near the Node, she is there seen to pass over the Face of the *Sun*; and as she is then describing that Part of her Orbit between the *Earth* and the *Sun*, she must necessarily appear to have a retrograde Motion, and enter the *Sun's* Disk on the eastern Side, as, I well remember, you shewed me in a former Lesson on these Subjects: all which gives me a clear Idea of the astronomical *Rationale* of this famous Transit.——Then, with regard to the *Earth*, I perceive it moving with a diurnal Motion analogous to that of the real *Earth*.——At the Beginning of this Motion, the Index points to II o'Clock in the Morning, and the Island of *Great Britain* then is in the darkened Hemisphere; and I have the Satisfaction of seeing, in one View, how all the Parts of the *Earth* are situated in the enlightened and dark Hemispheres, which gives me a clear Idea of the Times in which the Beginning of the Transit will happen to all the Parts of the *Earth* where it will be visible, and of all other Parts of the Globe where it will not be seen.

Cleon. Here I must interrupt you for a Moment——you remember that some Mathematicians were sent abroad to observe the Transit in distant Parts of the World: their Destinations were originally to the Isle of *St. Helena*, and to that of *Sumatra*: the first of which you observe near 16° of south Latitude, and about $6^{\circ} 30'$ West of the Meridian

Meridian of *London*, and therefore far from the enlightened Hemisphere at the Beginning of the Transit, inasmuch, that they only arrive to it just Time enough to observe the End of the Transit in the Morning; nor had they any other View originally, in their Deputation to *St. Helena*, than of viewing the End of the Transit near the Horizon, that they might have the greatest Parallax of Altitude, which in that Case would be nearly equal to the horizontal Parallax of the Planet.——But with Respect to the Isle of *Sumatra*, or *Bencoolen*, the Design was there to observe the Times of the Beginning and End of the Transit both, and consequently the Duration of the Whole, in order to compare it with the real Time of Duration as observed from the Center of the *Earth*; and for this Purpose, you see this Island is situated most advantageously in the enlightened Hemisphere;—but, by a Paragraph in the late News-Papers, we understand this great Design is frustrated; for, by that we learn, that those who went out in the *Sea-horse* for that Department, were obliged, by ill fated Incidents, to put in at the *Cape of Good Hope*, whose Situation, as you see on the Globe, at the Time of the Beginning of the Transit, is far within the darkened Hemisphere; and consequently the most interesting and important Part of the Phænomenon, and which was their particular Business to observe, was wholly invisible to them. For as the *Cape of Good Hope* has a greater South Latitude than *St. Helena*, and a less Distance from the enlightened Hemisphere, the Parallax both of Altitude and Longitude will be much less there, and consequently the Observations made at the *Cape* will be of much less Consequence than those at *St. Helena*, and therefore answer no Purpose at all: So that the Share which *England* is to have in the Discovery of the Parallax of the *Sun* is not likely to be great, unless any of our Nation at the Factories in the *Indies*, for the Honour of their Country, or their own Curiosity, should be excited to make their Observations at the Beginning and End of the Transit very nicely.

Euphros. This will be a very ungrateful Piece of News to the curious Part of the Public, especially to those who could wish to see *England* as renowned for the Improvement of astronomical Science, as by the Success of its
Arms.

Arms. — By this Time I see the *British* Isle is just upon entering the illuminate Hemisphere, and the Index now points to about $\frac{3}{4}$ after II: — But the *Cape of Good Hope* is still in the Dark. — And just now I perceive the artificial Planet, or Patch, just rising above the Horizon, and so far advanced on the Solar Disk as it appeared to those who had the Pleasure of viewing that Part of the Phænomenon. — As the Motion of the *Earth* continues, the Parts of the Surface are successively brought into, and carried out of the enlightened Hemisphere, and *England*, amongst the rest, gradually proceeds towards the middle Part of its diurnal Arch. — In the mean Time, the Planet regularly advances on the *Sun's* Disk, — and is nearly in the Middle of her Path when the Index of the Globe points at VI. — The *Cape* now enters the Sun-beams, and observes the Transit more than half over, while the *Sun* is not yet risen to *St. Helena*. — The *Earth* keeps revolving uniformly upon its Axis, and, at length, brings *St. Helena* to enter the enlightened Hemisphere, and soon after views the End of the Transit at a small Altitude of the *Sun* above the Horizon. — I observe the artificial Planet to be now much about that Position of the *Sun's* Disk as when I first saw it through the Telescope, viz. about seven o'Clock in the Morning of that memorable Day. — The Motion here of the Planet, I plainly see, is every Way similar to that of the real Planet on the *Sun's* Disk. The Motion of the Planet and the *Earth* being perfectly correspondent to each other, at length the Patch arrives at the western Limb of the *Sun*, and shews the internal Contact of the Planet at the Time the Index points to a few Minutes after VIII in the Morning. — And it is very curious now to observe the *artificial Egress*, which seems in every Respect to bear a proper Resemblance to that of the natural one. — The artificial Transit is just now at an End, for the Patch is now in external Contact with the Limb of the *Sun*. The Index of the Globe now points to nearly half an Hour after IX, so that I observe the Time of the Egress here is about eighteen Minutes, which is the same as was observed of the real one. — In the last Place, I see the Position which our Island had on the enlightened Hemisphere at the Time of the total Egress, and also the relative

tive Situation of all other Places where that Phænomenon could be seen.—And now, *Cleonicus*, I must acknowledge that you have, by this Means or Contrivance, conveyed to my Mind as perfect a Knowledge of the geographical and optical Principles of the Transit, as I could possibly have from any artificial Machinery, and, for your Care and Trouble herein, shall ever think myself highly indebted.

Cleon. It ever was, and will be my Study to represent the various Phænomena of Nature in such a Manner as may most exactly correspond with the Operations of Nature itself; and nothing will more felicitate my Success than the Pleasure and Instruction that may thence redound to one who is so dear to me as yourself.—I fear I have, by this Time, proved tedious; but you will remember, it is upon a Subject that, like the *secular Games*, happens but *once in an Age*.

DIALOGUE XII.

Concerning the NATURE and USE of BINOCULAR TELESCOPES.

Cleonicus.

OUR last Conversation was a Digression from our Speculations on the *Nature and Use of optical Instruments*. But it happened very opportunely to a most signal Instance of the latter, as I then observed to you.—I shall now return to the former Subject, which I shall re-assume with the Consideration of the *Nature and Use of Binocular Telescopes*.—We have already largely enough descanted on the common Constructions of this Instrument; but as the Binocular Telescope is of a different Form, and has a very peculiar Property, I thought it might be worth while to speculate on the Nature of it for an Hour.—A *French Author* formerly (*P. Cherubin*) had so high an Opinion of this Instrument, that he wrote a large Volume in Folio almost wholly upon the Subject; and,

and, indeed, ever since their first Invention, their Effects have been greatly admired by all who delight in Optics.

Euphros. If I can judge from the Sound of the Word, this Instrument employs *both the Eyes*; — and as I presume the Instruments you speak of, are those before us, they appear to me to be a *double Telescope*, one of the refracting, and the other of the reflecting Kind.

Cleon. You observe very rightly in each Respect; the Binocular Telescope consists only of the Glasses of two common Telescopes, properly adjusted, to shew the same Object to both Eyes. — You will readily conceive the Design and Utility of this Construction, by considering how great the Advantage of common Vision by two Eyes, is, in Comparison of that by one only: It hath been usually made an Argument of a most obvious Providence, that Animals are in general furnished with two Eyes, that they might not be dark with the Loss of one; but we may add to this, the great Pleasure and Perfection of viewing Objects with two Organs of Sight instead of one: Nor is this at all difficult to be experimented, as I make no Doubt you have oftentimes had the Curiosity to try.

Euphros. I have many a Time tried that Experiment, and found the Difference very sensibly: — The Field of View is not only more confined by shutting one Eye, but the Objects are less vivid and bright, and seem, as it were, diminished and contracted to the View.

Cleon. It is all very true that you say; but it is very observable, that the Difference is nothing like so great to the naked Eye as by the Telescope, where, as we may say, this very Difference is magnified in Proportion with the Objects themselves; and this is that very wonderful Effect that I just now mentioned, and which so strongly recommends this Instrument to all the Curious.

Euphros. But how are the two Telescopes adapted to exhibit one Idea of the Object only: One would think, that, by two Telescopes, we should have two different Views of the same Object?

Cleon. The natural Reason of this is the same as that by which an Object appears but one and the same to two naked Eyes, notwithstanding there are two Images formed, one in the Bottom of each Eye. For by the wonderful
Disposition

Disposition of the nervous System, the two optic Nerves are united in the same Part of the Brain, where the Sensations of each Image, or the Ideas which they occasion, are united in one, and so present it to the common Sensory of the Mind; and you will easily conceive that the Telescope, single or double, does not multiply the Image, but magnifies it only. The Image in each Eye is still the same, but only larger; and therefore two Telescopes only produce two larger Images to the Eyes, instead of two small ones, and consequently the Mind has still the *single Idea* of the Object, but enlarged.

Euphras. I presume, this is pretty much a parallel Case with those who use Spectacles; for they, with two Glasses, see the Object enlarged, but single at the same Time.

Cleon. Your Comparison will hold, provided the Spectacles you speak of are disposed as they ought to be, (but those of the common Make are not,) viz. when the Axis of the Glasses are both directed to the Object that we view, and there intersect each other: And this is the Case of the two Telescopes which compose this Instrument, the Axis of each are so directed, by adjusting Screws, as to point to, and terminate in the Object we look at; for, in that Case, each Telescope presents the same View, enlarged, as we have in small, by the naked Eye: Thus, two Telescopes, in that Respect, have the Effect of one, with this important Addition, that the Field of View in the Binocular Telescope, though really the same as in the single one, is yet seemingly vastly enlarged, at a greater Distance, shewing the Objects more strong, bright, and perfect, than they usually appear; which is one of the most agreeable and noble Deceptions that can be found in any optical Instrument, of which I shall now gratify you with an Experiment, having first observed to you, that while we look through the Instrument, it is necessary to turn two Sets of Screws, to adjust it to the Eye, one which moves the Object-glasses, and the other the Eye-glasses, nearer to, or farther from each other, till the Axis of each Telescope coincide with those of the Eye and nicely meet in the Object.—— In this Manner I have now adjusted the Refracting Binocular, and now, if you take my Place, you will

see yonder House in the most agreeable View you ever beheld it.

Euphros. I do, sure enough.——I find every Thing just as you have described it:——With both my Eyes I see the Field of View, in Appearance, wonderfully enlarged: The Appearance of the House more natural, easy, and vivid.——But when I shut one Eye, then I see the very great Difference you speak of, the Field, as it were, seems contracted as well as the Objects; and every Thing has a poor and unpleasant Aspect in Comparison of the former.——To tell you the Truth, *Cleonicus*, you will, by this Experiment, put me out of Conceit with the common Telescopes.——I can scarcely think I should reason well if I used a single Telescope instead of a double one, any more than I should, if I preferred viewing Objects with one Eye instead of two—Pray, is the Effect nearly the same in the Binocular Reflectors?

Cleon. It is there in Proportion heightened, as they magnify more than the Refractors:——I have fitted them for your View:——Look now at the same Object through them.

Euphros. Well, this is wonderful indeed:——I may truly say I never knew what it was to view Objects through a Telescope before. I have seen them indeed magnified, and thought that was a wondrous Effect; but I scarcely know how to express the different Sensations which arise from a Prospect of the same Objects in this compounded View:—Here is truly (*je ne sçay quoi*) something inexpressibly delicate, grand, and delightful in the Effect of this Instrument!—It is amazing to me, that every Lady or Gentleman of Fortune and Curiosity has not one of these Binoculars in their Possession.

Cleon. You might be in an eternal Amazement if such Things were to excite it; the Case is so far otherwise, that you seldom observe the Purchase of any Instruments is in Proportion to their Merit and Uses: Things in common Vogue, that give us no Trouble to understand their Use, and which have been made Time immemorial, are mostly the Subject of common Demand; few enquire after new, or more perfect Improvements.——But yet, I cannot help wondering a little, with you, that there are not more of those curious Persons than we find; so very

few there are, that I never saw but one of those Binocular Reflectors, yet, in any Gentleman's Collection of *optical Instruments*, and yet there is nothing in the Price that is so very extraordinary, or difficult in its Use, that might deter People from having them. Especially as to the Refracting Binoculars, whose Expence and Use are both very reasonable and easy. Of these there were no less than three or four of different and very curious Construction in the Museum of his Grace the late Duke of Argyle.

Euphras. And was I a Duchess, I would have as many, and every Instrument of every Form and Construction that could afford me any different Pleasure and Instruction; and I should always look upon those Instruments as the principal Furniture of the choicest Apartments of my House.

Cleon. There is yet another optical Instrument, which, at our next future Leisure, I shall describe to you; and though it has no magnifying Power for distant Objects, is not without a Variety of Uses adapted to the Amusement of Ladies and Gentlemen, and with which, I dare say, you will be very well pleased.

DIALOGUE XIII.

The Description and Use of an OPTICAL INSTRUMENT for measuring the ANGLE of VISION, the apparent MAGNITUDES, and DISTANCES of Objects; for viewing perspective PRINTS, PICTURES, Intaglios, &c.

Cleonicus.

I Shall now present you, my *Euphrosyne*, with a small optical Instrument that is not only designed for Amusement, but many considerable Uses.

Euphras. It makes but a small Appearance, it is true; but the Value and Uses of Things, in general, depend very

very little on their Bulk.—Pray, what are the Peculiarities of this Instrument?

Cleon. I shall relate them to you in Order, and exemplify them by Experiment: One Thing, however, I shall premise with respect to the Nature and Construction thereof, as it is a Property quite peculiar to this Instrument, and that is this, *viz. that it gives you a clear View of distant Objects, without magnifying them at all, and, at the same Time, it presents you with a magnified View of Objects near at Hand, by a proper Change of Glasses.*

Euphros. Pray, what, and how many Glasses have you in this Instrument?

Cleon. There are essentially no more than two required, and those both of the same Form, or Figure, and consequently of the same focal Distance:—And, as to the Position, they are placed, as you see, one at each End of the Instrument, and from this Construction you will easily understand the Nature of the Instrument, from what I have formerly said of a Telescope with two Glasses; for in such a one, you remember, I told you that the magnifying Power was in Proportion of the focal Distance of the Object-glass to the focal Distance of the Eye-glass. Now, in this Instrument one Glass is to be considered as the Object-glass, by which an Image is formed; the other, as an Eye glass, by which it is viewed; but since these Glasses have an equal focal Distance, the Image will be equally distant from either Glass, and consequently there can be no magnifying Power at all with respect to distant Objects: For the Image will appear under the same Angle to one Eye applied to the Glass, as the Object does to the other naked Eye, and therefore they must appear equal, as you will find by Experiment.

Euphros. Pray let me try that Experiment.——I will place myself on this Side of the Room, and look on the Sash-window on the other Side, and see how the Quarries appear, in the Manner you formerly directed me by viewing it with one Eye applied to the Glass, and the other without it.——And now I perceive the Truth of all you say——Each Quarry in the Window is of the same Bigness in the Instrument as to the naked Eye, and, by properly removing it, I make the whole

Frame in the Image exactly coincide with the Appearance of the Window itself to the naked Eye: Which, therefore, fully proves that the Image and the Object are equal to each other.

Cleon. You will farther observe, that in the Construction of this Instrument there is a Screw and Cell in the middle Part, for another Glass; which is to be of the same focal Distance with the other Two, whose Use is to render the Field of View more perfect towards the extreme Part; by which Means the Eye may be applied nearer, and view the Object to much greater Advantage — You will satisfy yourself by the Experiment: For I have now put in the third Glass.

Euphros. It is really fact: The Images of all Objects that I view, appear in an enlarged, and a much more perfect Field, even to the extreme Circumference; this Glass is a great Addition to the Distinctness and Perfection of the Instrument. — But it is something of a Paradox to me, that a Glass, which, in itself, has so considerable a magnifying Power, should yet, when placed in the Instrument, appear to have no Effect of that Kind.

Cleon. Optical Glasses, applied in different Circumstances, will have different Effects; its Disposition in the Middle of the Instrument gives it no Power of magnifying, but only of perfecting the Field of View.

Euphros. The Image I observe is inverted; but that, I presume, is no Obstruction to the Uses you would make of this Instrument: — But, as it neither magnifies nor diminishes, I shall be glad to know wherein the Uses of it consist:

Cleon. That I shall now particularize to you. It is therefore to be observed, that since the Object and the Image appear under the same visual Angle, that Angle may be easily estimated, or measured by this Instrument, by adapting a MICROMETER to the middle Part, where the Image is formed in the common Focus of both the Glasses, which Micrometer may be made of many different Forms, viz. (1.) With a Screw having very fine Threads, or (2.) by Means of parallel or equidistant Lines drawn on a circular Piece of plain Glass very near to each other; or, (3.) by two Hairs moving parallel to each other.

ether in a small brass Frame placed in the middle Part of the Instrument.

Euphros. How, by Means of these Micrometers, you measure a visual Angle, be pleased in the next Place to explain to me; for, as yet, I am not acquainted with these Instruments of Measure.

Cleon. A MICROMETER is an Instrument of great Use in the nicer Computations of Astronomy, which concerns the Magnitudes and Distances of the heavenly Bodies: But, in the Use of this Instrument, great Exactness is not required; and therefore a Micrometer made of a Screw will answer this general Purpose as well as any, and will be more simple and least expensive of all others; and a Screw that has *forty Threads in an Inch* will be sufficient for this Purpose. Then, if the focal Distance of the Glasses be *one Inch*, the Angle, which is subtended by the Interval between two of those Threads, will be $1^{\circ} 26'$, and two will subtend an Angle of $2^{\circ} 52'$, and 3 Threads will subtend an Angle of $4^{\circ} 18'$, and so on; the Angles and their Subtenses being very nearly proportional, when very small, and therefore, by observing how many of those Threads of the Screws the Image of any Object occupies, it will be known from thence what the Quantity of the optic Angle is under which it appears:—And if a Screw has a greater Number of Threads to an Inch, as suppose 60 or 80, the Accuracy of the Instrument in measuring the optic Angle will be in such Proportion greater ——— But though this Use of the Instrument may the least concern you, yet it may be oftentimes of great Importance to those who are concerned in measuring the Angle under which distant Objects appear, which are generally very small, in order to form a Calculation, or an Idea of their Distance, by previously knowing the Dimensions of the Object. Thus, for Instance, by knowing the Number of Feet in the Length of the Cross on the Top of *St. Paul's*, and observing, by this Instrument, what Angle it subtends to the Eye, a Person will immediately find, by the Rules of Trigonometry, what Distance he is from that Object.

Euphros. This is an Affair of too mathematical a Nature for me; there are others, I presume, more adapted to

my Understanding, which may afford me some Degree of Pleasure and Curiosity.

Cleon. There are, most certainly; the next I shall mention is one of them, which is, that by Means of this Instrument we may easily judge of the comparative, or apparent Magnitude of Bodies: For when you would compare the apparent Magnitude of any two Objects, you only move the Instrument in such a Manner, as shall bring the Image in each Object successively upon the Threads of the Screw, and then observing how many of those Threads are occupied by each. Thus, for Example, if the Image of one Object was equal to the Distance of two Threads of the Screw, and another measured three Threads; then their apparent Linear Dimensions would be in proportion as 2 to 3, and their Surfaces in Proportion to the Squares of those Numbers, viz. 4 to 9, and their Solidities as the Cubes, or as 8 to 27: And thus the comparative apparent Magnitude of all distant Bodies may be easily estimated.

Euphros. This, I allow, is a very pretty and instructive Use of the Instrument, as nothing is more common than to hear People ask, How large do such or such Objects appear? whereas, it is impossible to give any Answer to such Questions, without a Method of comparing their Magnitude with that of some other Objects that we know; which, by what you have now said, I find is very easy to be done by such a *Micrometer*.

Cleon. Another Use of this Instrument, equally curious and amusing, is, to measure the Distance of any Object without any Skill in Geometry, or the least Degree of Difficulty: Thus suppose you observe the apparent Image of any Object upon the Threads of the Screw, then, if you walk so far backward till the Image of the same Object occupies but half the Number of Threads, or if you go forward till the said Image measures twice the Number as at first, in either Case you walk just so far as is equal to the Distance of the Object from your first Station; for you well know, the apparent Magnitude of Bodies increaseth or decreaseth very nearly with their Distances inversely, or, that at twice the Distance, they appear twice as small; and, at half the Distance, they appear twice as large.

Euphros. I belive I pretty nearly comprehend your Meaning: For, suppose I was on the Bank of a River, and I took, with this Instrument, the apparent Magnitude of the Body of a Tree on the other Side, and then retreat from the River, so far, till I observe the Image of the Tree occupy but one Half the Number of Threads as before; then the Distance I have gone back from the Bank will be just equal to the Width of the River, which by this easy Experiment becomes known.

Cleon. That is just the Thing that I mean; and, in like Manner, you may apply it to measure the Distance of many other inaccessible Objects.—Again, another Use of this Instrument is to view the Height of an Object, when you know the Distance from it: For, by knowing the Number of Threads in the Screw which go to an Inch, you, by that Means, know the Proportion of the Image of any Object to the focal Length of the Glass; and this is the very same as that of the Height of the Object to the Distance you are from it; and therefore you may only say, as the Number of Threads contained in the focal Length of the Glass is to the Number of Threads which measure the Image, so is the Distance of the Object to the Height of it; which therefore becomes known without any farther Trouble.

Euphros. This Application of the Instrument appears not the least considerable, to those who understand the Rule of Three. But you were mentioning some other Uses which would be still more interesting than these, viz. such as relate to viewing Prints, Pictures, &c.

Cleon. These Uses require a Change of Glasses in the Instrument; for as one principal Design hereof is to view distant and perspective Prints, one of the equal Glasses at the End must be changed, for another whose focal Distance is longer; for then that will add a magnifying Power to the Instrument: but this is upon supposition, that the Print or Picture that you view, is at a Distance from you, and in itself not very large, or greater than the usual Size of Family Pictures.—But if the Picture, or Print, be in itself very large, and near at Hand, as, for Instance, upon the Table before you, then will the Instrument, without any Change of Glasses, do; for in this Case a magnifying Power is not required,

the Image filling the whole Field of View, without it; and, indeed, that is the only Rule to be observed in all Cases whatsoever, that such a Glass be applied as will cause the Image of the Object to appear as large as the Field of View will admit of, and then the beautiful Effects of the Instrument will appear, *viz.* a most natural and fine *Relievo* of all the Parts: This will be better seen by Experiment, than expressed by Words.—Here, view the perspective Print before you on the Table, without changing the Glasses.

Euphros. It is a fine View of St. Paul's Cathedral, I see at once:—The august Pile rises to the View, and its majestic Dome and Cross appear sublime in the Air:—The Pillars all in proper Arrangement and Distance, and the whole Architecture appears in the natural and glorious Construction of the West Front: The spacious Area, or Court before, appears expanded and in the same natural Perspective as if I was viewing it from the adjacent Corner-shop in *Ludgate-street*:—The Pedestals are all erect, and her Majesty, with the other emblematical Statues, appear as natural and vivid as on the Spot.—Upon the Whole, I think this a sufficient Proof of the excellent Use of this Instrument in viewing perspective Prints.

Cleon. But you will be easily convinced that the same Glasses will not suffice for viewing Prints hanging at the opposite Side of the Room, as the Image will be there too small for all its Parts to appear distinctly: For your Satisfaction, I will place the same View of St. Paul's, with a good Light, at that Distance, and then you may view it with the same Glass.

Euphros. I do as you instruct me;—I view it, indeed, but not with the same Satisfaction as before:—It is in Perspective, I confess, but the Appearance so diminutive and indistinct, as convinces me, that some Degree of magnifying is now necessary.

Cleon. I will change the Glasses, and apply one proper for the Purpose, and then you will observe the same Effect nearly as before.

Euphros. It is very true; the sumptuous Pile has now the same Appearance of Grandeur as to the naked Eye.—But now let me view a Landscape, or some such large perspective Painting.

Cleon. I will go and invert two or three for this Purpose, without letting you know what they are till you view them.——There is one now ready, can you tell me what Part of *England* you see?

Euphros. Yes, that I can without Hesitation:——I must necessarily consider myself on the Summit of *Richmond-Hill*, and there surveying the beautiful Scenes of the distant Country and Villas all below:——The perspective Diminution and tortuous Irregularity of the noble Stream;——the Forest, Fields, and Lawns, all attract the wondering Eye:——But what a Change have you suddenly made, from so delightful a Scene to one so shocking to human Nature!——Cathedrals, Palaces, and the most beautiful Ranges of Houses, all in one confused and ruinous View!——Methinks I see a City all in Commotion, and falling by the tremendous Shocks of an Earthquake! This, the more I am satisfied, is a View of the terrible State in which *Lisbon* has lately, and often appeared, from its most inauspicious Situation.——The Scene is again most wonderfully changed; the River of a fine and flourishing City now regales my View; and the glorious Appearance of a Bridge, constructed with one Arch, makes me fancy myself at *Venice* viewing the *Rialto*, so famed throughout the World.——These Instances of perspective Views are sufficient. Let me next see what is the Effect in viewing Portraits and family Pictures.

Cleon. I must take one down, and put it in an inverted Position, for the Reasons I have heretofore mentioned: It shall be that venerable old Face of your Grandfather, of which you have often expressed so high a Value; for, by this Instrument, you will see how properly, and with how much Reason you do it: Take a View of it.

Euphros. Upon my Word, it almost reinstates him in Life.——The Face, as it were, starts from the Canvas, and the poor old Gentleman seems to regard me with so natural a Smile, as if he knew me in the near Relation,——his Eyes seem lively and percipient,——they sink very naturally under his Brow,——his Nose properly projects from the Face: in short, his whole Mien, or Countenance, is such as plainly bespeaks him a Man of that Sedateness and contemplative Disposition
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for which he was so remarkable when living.—By these Experiments, I am satisfied how useful this little Instrument is for this Kind of Views.—What other Uses yet remain?

Cleon. Several: One of which will not a little delight you, I am well assured.—For now, if to the two equal Glasses I add a third of the same focal Distance with them, and the Intervals of the Glasses be respectively equal to twice their focal Distances, then is it fitted for viewing, in a peculiar Manner, all Intaglios, or deep cut Figures in precious Stones, Seals, &c. for then they appear just contrary to what they are; viz. as Cameos, or with a Bass Relief, as you will easily observe by viewing the Head excavated in this Seal.

Euphros. This is something very odd, indeed; that the Head, which I know to consist of a hollow Cavity in the Seal, should now appear with so perfect a *Relievo* above it; I see every Part of the Head, Hair, Face, and whole Bust, just as plain as the *Cameo*, or Impression on the Wax:—And from the Picture and Bust, which I have often seen of Sir *Isaac Newton*, I guess this to be a Representation, in Miniature, of that celebrated Personage.

Cleon. It is, indeed, that venerable Man:—But the Excellency of the Instrument, in this Respect, consists not so much in the Conversion of a Figure, as to enable you to examine the Perfection of Work of this Kind; for the Glass will, much better than the Wax, shew you the Care and Skill of the Artist in the Execution: Nor can you, any other Way, be so thoroughly satisfied of the Value of his Performance, or the Estimation which it really deserves. These Glasses, therefore are of the utmost Service to Engravers, Jewellers, &c. as well as to Ladies and Gentlemen of Curiosity and Fortune.

Euphros. But before we drop this Subject of *Intaglios*, I shall be glad to be informed of the Reason of so odd, or rather contrary Appearance of the Object.

Cleon. This is one of the most celebrated optical Paradoxes, and is equally curious and inexplicable; there is scarce any thing in the optical Science so directly contrary to the known Laws of Optics as this very Phenomenon:

menon : For it is most certain, that the Image formed of the hollow Object is still a deeper Cavity than the Object itself, and therefore one would naturally expect to see the *Intaglio* concave in a higher Degree ; whereas, on the contrary, it is so much more a *Cameo*, or the *Relievo* in Proportion higher.——In Perspective, a Semi-circle being drawn on a proper Ground, may be made to appear as a convex or concave Hemisphere, at Pleasure, by a proper *Claroscuro*, or Disposition of Light and Shade ; but here, without any Assistance of Art, a more wonderful Effect of the same Kind is produced ; not a plain Circle, but a concave Hemisphere is in any Sort of Light raised into a perfect convex one.——The true physical Reason is as yet dubious among the learned in Optics, and it would prove an unentertaining Disquisition to trouble you with it at this Time.

Euphros. Are there any farther Uses to which this Instrument may be applied ?

Cleon. Yes, of very considerable Importance ; no Instrument being better adapted for shewing, to the greatest Advantage, all Kinds of Fossils, Minerals, Ores, Earths, &c. either with a Magnifier that is now on, or others that might be placed in its Room :—See the Ore which I have now placed under the Glass

Euphros. I do, indeed, view a fine bespangled Surface of something ; but had you not said it had been an Ore, I should not have known what it had been :——I see the metalline Particles curiously interspersed, and incorporated with the stony Matter of the Ore.——I could not have thought the Metal had been so distinctly visible in its natural State as I now perceive it to be.——By the Colour I guess it to be Silver, as it appears not in the least disguised in the Stone :——But what gratifies my Eyes in the highest Degree is, to observe the most curious Vegetation of the metallic Matter,——it evidently shoots into various Sprigs and Forms, in many Places like a Kind of Ramification ; and, in others, the Representation of a beautiful Foliage.——Surely, *Cleonicus*, this is a very rich Piece of Ore, as I see it so very replete with silver Particles, over all the Surface exposed to View.

Cleon. It is so rich, my *Euphrosyne*, that one Pound of this Ore contains near four Ounces of Silver.——But
now

now I will place under the Glass another Sort of Ore,—see, if you can tell me what it is.

Euphras. By the fine Appearance it makes, of a rich gold Colour, I judge it to be a Piece of gold Ore.

Cleon. I thought you would be mistaken, on that Account; and you see, from thence, how easy it is to be deceived by Appearances:——The Ore which you now view is not Gold, but Copper Ore; and what you see in such brilliant golden Colours is neither Gold nor Copper, but what the Miners call *Mundick*, a Matter of little Value in itself, and only remarkable for its fallacious Mimicry of Gold.——In like Manner you may, at your Leisure, view all other Species of Ores and terrestrial Substances, which will afford you a most instructive Amusement.

Euphras. I shall be sure to embrace every Opportunity for that Purpose. What is the next Use of this Instrument?

Cleon. By screwing on another Glass at the Bottom, in the Room of that which is now there, it is converted into a common Microscope for viewing any Sort of small Objects; but, as this will afford you nothing new, it need not be farther insisted upon.——You will observe, upon the Whole, that this one Instrument is capable of being applied to almost all optical Purposes:——I have placed it on a proper Foot, or Stand, by which it may be readily applied to any proposed Object, and, as such, shall desire your Acceptance of it. There remains yet one Instrument more, that shall be the Subject of our next Discourse*.

* The instrument here described, is now made with considerable Improvements, under the Title of the *Graphical PERSPECTIVE* and *MICROSCOPE*, for delineating all Objects in *true Perspective* and just Proportion of their Parts.

DIALOGUE XIV.

The CONSTRUCTION and Use of the LANTERNA MEGALOGRAPHICA, vulgarly called, The MAGIC LANTHORN.

Euphrosyne.

PRAY, *Cleonicus*, what Compliment do you intend to make me by this Instrument, which I see is a *Magic Lanthorn*, whose principal Use, as I understand, is to divert Children with the Appearance of ludicrous Objects?

Cleon. The Compliment I shall make you is no other than the Knowledge of the Construction, and proper Uses that might be made, of a noble optical Instrument, whose Nature and Use have been but little considered, and those applied to serve the lowest Purposes, by which Means this Instrument has been brought into Disgrace, and acquired the vile Name of *Magic Lanthorn*:—But the Abuse of Things, by the Ignorant, does not alter their Nature; and because this Instrument is capable of exhibiting a large and surprizing View of any odd, ridiculous, or monstrous transparent Picture, and thereby occasion Wonder and Surprize to an inconsiderate Populace, it does not by any Means follow that Ladies and Gentlemen, nay Scholars, and Sages themselves may not be very rationally amused with the curious and noble Effects which such an Instrument can produce with proper Objects applied to it. A precious Stone is not of less Value for being worn on the Finger of a Show-man, and there is nothing in the *Magic Lanthorn* that is scandalous, but the Name itself; so desire you will not think yourself affronted by having this Instrument set before you.

Euphros. I only joke with you, *Cleonicus*, as I know the Reputation this Instrument is in.——But, pray, how comes it to be called the *Magic Lanthorn*?

Cleon. From the wonderful Effects which it was observed to produce, by the stupid and superstitious Part of Mankind, and the Villany of Cheats and Impostors. For,
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on the first Invention of this and such like Instruments; it was well known how the Minds of ignorant People would be influenced by such amazing Effects; and as it was easy to conceal the Cause, the Conjuror had it, by this Means, in his Power to work Miracles, and multiply the Experiments of his Magic Art; and it is not to be doubted, the Tribe of Miracle-Mongers found their Cause of Imposture to be as much promoted, by this Instrument, among their credulous Votaries, as by any one Instrument that ever fell into their Hands:—

But after all, nothing more has been done with the Magic Lanthorn, to answer the execrable Views of Sorcerers, than is daily practised with the Bible itself, by the Professors of pious Frauds, in almost every Age and Country: and it is most certain, that if there were no Fools, there could be no knavish Pretenders to the Magic Art; nor should we ever have heard of any such Thing as a *Magic Lanthorn*.——We shall therefore discard the infamous Appellation of *Magic*, and substitute in its Room the true and deserved Epithet of *Megalographic Lanthorn*, by which the Nature of the Instrument is, as it were, deciphered and explained, as signifying nothing more than the *producing a very large and magnified Picture of a small Object*.

Euphros. This Instrument, then, I suppose is to be used by Candle-Light, as you have chosen the Evening to discourse of it, and from thence I conclude, that it has some Affinity to the Solar *Megalaoscope*, which you some Time ago explained the Use of to me.

Glean. It is in Effect almost the same Instrument; it differs, it is true, in Form, and requires the Candle-light, as the other does that of the Sun: But as a small Quantity of the Sun-beams will suffice in a Megalaoscope, and in the Megalographic Lanthorn a very great Quantity of Candle-light is necessary, therefore the Lanthorn must necessarily exceed the Megalaoscope in Bulk, as it must contain the Candle itself, and a large Speculum, or Lens, by which the Light may be collected sufficient to illuminate the Objects that are magnified: and hence arises a two-fold Construction of this Instrument, viz. with a Speculum and Lens conjointly, and the other with Lenses only.

Euphros. This, I suppose, is the Reason why I see two Lanthorns here before me, one of a large, and the other of a smaller Size.

Cleon. It is so: The large one, as you will see on my opening the Door, has a large Speculum placed on the Back-part, or Left-hand, which collects the Light of the Candle placed in the Middle of the Lanthorn; and then reflects it to the transparent Images on the Glass, to illuminate them strongly, and then the said Object is magnified by a glass Lens in a sliding Tube, which adjusts it to a proper focal Distance; and because the Speculum is large, and the focal Distance 12 or 15 Inches, therefore the Lanthorn of this Construction must necessarily be of a very considerable Bulk. — But in the other Lanthorn, upon opening the Door, you see only a large, thick Lens (almost a Hemisphere) of Glass placed between the Candle and the Objects; and though in this Case the Surface of the Lens be not near so large as that of the Speculum, yet, on Account of its much shorter focal Distance, the Rays of Light will be sufficiently strong for a requisite Illumination of the Object.

Euphros. I think, if I remember right, the Objects made use of in these Lanthorns are all painted in square Panes of Glass, and in transparent Colours, which are disposed together in a wooden Frame to be applied for Use.

Cleon. They are so; for it is necessary the Colours, should be transparent to render them vivid and lively in their Images magnified as large as the Life: — As the Objects themselves are some of them two or three Inches long, therefore a large Lens will be necessary to be used; for the Lens and its Aperture must be proportioned to the Size of the Object in this, as well as in all other optical Instruments; and then it will be easy to know what Distance the Lanthorn must be placed from the Wall, in order that the Portrait of a Person two Inches long may form on the Wall an Image of six Feet high; for if the Lens which magnifies it has its Focus at about six Inches Distance, then it will be as two Inches to six Inches, so is six Feet to eighteen Feet; therefore, if the Room be 18 Feet wide, the small Pictures of Men and Women will be formed on the Wall just

as

as large as the Life; and therefore, when those painted Objects are properly chosen, this Instrument may afford as agreeable an Entertainment, and excite as much rational Laughter, as any one that I know of. And here I must observe to you, that among the old dull Classes of Schoolmen, *Risibility* was esteemed no inconsiderable Faculty of human Nature, and, in their Logics and Metaphysics, they often considered it as peculiar to, and a distinguishing Characteristic of Man; and surely such Faculties were never bestowed upon us in vain: and therefore the Amusements of the Megalagraphic Lanthorn, if they were considered in no other Light than that of Recreation, are worthy of rational Beings, and, consequently, far from being impertinent.

Euphros. As you put so good a Gloss upon the Matter, you have excited my Curiosity to see a few Experiments at this Time, though I cannot help thinking, after all you have said, they will look like Puerilities, or Entertainments fit for Boys and Girls only.

Cleon. We may see the Force of Prejudice against Things taken up in a general Way, in this one Instance of your almost invincible Indifferency to this poor, degraded Instrument: For my own Part, I could heartily wish we had no Opportunities to observe our valuable Moments of Time spent on Subjects of Amusement more puerile, or trifling than these: However, I must entertain you with something of this Kind, and, because the Subject shall not be low, I have procured an Artist, well skilled in this Miniature Painting, to draw on two or three Slips of Glass the whole PROCEEDING of the late CORONATION, which, when you observe the Motion on the Wall, you will certainly have a different Idea than what you have hitherto entertained of these Subjects.—See, I put the Slips in, one after another, and will move them in a proper Manner, while you take a cursory View of them as they pass in the regal Procession.

Euphros. This will be an elevated Subject, indeed:—Good Heavens! The Herb-Woman appears at a greater Advantage than when I saw her on the Platform at the Time. The Painter has certainly complimented her six Maids.—The Flowers lie as naturally on the Carpet as I then saw them:—A delightful Appearance, indeed;

indeed; the various Orders and Degrees of Gentry and Nobility, with their proper Habits, Robes, and regal Investments, bring to my Mind so naturally the Thing itself, that I really judge this View, by Candle-light, much to exceed that by Day-light, if it may be so called when they returned from the Abbey.——The Canopies, under which our Sovereigns walk, are very elegant and highly improved by the Painter's Hand:——The King and his Royal Consort appear with all the Pomp of solemn Majesty.——Upon the whole, it is a most exquisite, grand, and beautiful Scene; and were such Subjects as these to be used for this Lanthorn, I cannot say but I should be as much entertained with its Effects as any of my Sex.

Cleon. But this is still in the Way of Entertainment only, nor has the Instrument as yet been ever applied to any other Purpose, though it be very capable of it.——I shall give you some particular Instances of the superior Use of this Instrument.——In the first Place, observe the Object which now passes over the Sheet upon the Wall.

Euphras. I know the Object at its first Appearance, having seen it before in the *Megalascope* of the *Camera Obscura*:——It is a Leaf dissected, or anatomised, and all its curious Ramifications and Contexture exhibit a delightful and instructive Spectacle to the Eye.——What other Objects of this Kind can you put into the Lanthorn?

Cleon. In the general Collection of marine Vegetables, or Sea Plants, with which you were some Time ago presented by an eminent Virtuoso, I observed you was not a little delighted in recounting their various Species, and observing and reflecting on their peculiar Nature and great Variety of beauteous Forms; you have likewise employed many Hours in sorting them out, expanding them on Paper, and disposing of them in proper Frames, which you now look upon as the most ornamental Part of your Study:——You have likewise farther observed, that most of those Marine Plants are transparent, and variegated with Colours the most delicate to be found in Nature: These Qualities, therefore, render them a proper Subject for the Megalographic Lanthorn.—Accordingly, I have selected a Specimen or two of that Kind,
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and placed them on Glass in a Frame of the usual Form, that you may see them, one after the other, upon the opposite Wall.

Euphros. They are, indeed, as fine a Spectacle as Eyes can behold.—I thought they made a glorious View in my Frames; but how infinitely short does that fall of the Glory and Grandeur with which they now appear! —They seem to be each of them a new Species of large, or full grown Trees, with Limbs and Branches resembling transparent Coral, of all the Variety of exquisite Colours:—The Form, the Texture, and Substance of these Plants, I really think, could not be shewn in any other Way to so great an Advantage.

Cleon. There is no other Instrument that has yet been made for shewing an Object so large in the Sun's Light; the common Megaloscope takes in an Object of little more than an Inch in Diameter, which is too small for shewing these curious Plants, or any other large Objects, to the greatest Advantage; though such might be made, and applied to the same Purpose, in the *Camera Obscura*, as you have now seen by Candle-light; but the Glasses for this Purpose must be large, and the Instrument of Course more expensive than the common Solar Microscope; and it is very probable, that I shall have it in my Power, ere long, to entertain you with one of this Kind,—But to return to our Subject:—There are yet other Uses to be made of this *Megalographic* Instrument, since every Subject that is transparent, immediately becomes applicable to it, and, though small in itself, yet, being hereby rendered extremely large, becomes in Proportion more agreeable to the View: Thus, for Instance, supposing you have Glass Medals, or Glass Pictures of perspective Views, these, illuminated and magnified in this Instrument, would have a very noble and fine Effect to the Eye, if properly ornamented and tinged with natural Colours.

Euphros. I suppose, by your Manner of speaking, that you have some such like Curiosities to entertain me with; and I cannot say but, from the Nature of the Thing, they must, when this Way applied, yield a very delightful Spectacle.

Cleon. You have conjectured right: For though I have not real Glass Medals, yet I have procured such as will

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answer the same Purpose, and in a much better Manner, and which, I am well assured, will give you no small Pleasure when you are perfectly instructed in the Method of manufacturing them for your Use.—What I mean is, a Collection of very curious Impressions, clear and transparent as Glass itself, and yet without that unlucky Property of its Brittleness; and so they are never in any Danger of being broke.—Another valuable Property is, that they are thinner than any Wafer, and 100 of them may be put in a *Frank*, and transmitted, by the Post, from one Part of the World to another.—The Nature of these medallic Impressions disposes them to receive, and represent the finest Strokes that can be drawn by the Hand of the Engraver, and therefore will appear a more sharp or perfect Representation of the Medal, than can be expected from Plaster of *Paris*, or any such earthy Matter.—Again, their Colour greatly favours a View of the Impression; for you can scarcely find any Colour ground that will shew them to a greater Advantage than their own natural Colour—But, if you chuse it, you may tinge them with any Colour you please, by mixing proper Dyes or Tints with the Substance of which they are made.—See here, a great Variety of different Sorts, Sizes, and Impressions.

Euphros. A rich and beautiful Variety, indeed; to my Knowledge, I never saw any Thing of a more curious and delightful Appearance:—They represent the Busts of Men and Women in *Relievo*, as naturally as the Medal itself:—The curious Portraits, perspective Designs, and Landscapes, in Miniature, are taken off in a most elegant Manner, and must have a noble Effect when magnified in this optical Machine.—I observe, among others, the Impressions of their present Majesties, which, I suppose, you have made from the Coronation Medals:—There is all the Majesty and graceful Mien of the King, by which he is so easily distinguished and known; and a greater Likeness in the Side-view of his Consort Queen, than has yet appeared, in my Opinion, in any Print.—I shall be greatly delighted to see them represented at large, by the magnifying Power of the Lanthorn.

Cleon. I have them already disposed in proper Frames for the Purpose:—and now, upon the Wall, you see

their Majesties almost as large as the Life, and by this Method alone can they be represented so in any Perfection; for if these Figures be compared with those painted ones you see before you, the Perfection of these Representations will as much exceed the others, as the fine Art of Engraving exceeds the common tawdry Painting of Water-colours ——— Here you see Nature itself heightened with all the Majesty of ornamental Decorations and Attitudes, as far as the Skill of the Artist can perform, and all exhibited in full Perfection in these magnificent Views; ——— But, behold! a City now rises to the View.

Euphros. Surely, it makes a very grand and natural Appearance. What does it represent, *Cleonicus*?

Cleon. It is an Impression taken from a Medal of a perspective View of the City of *London* before the Fire, where you now see the ancient State of this great Metropolis, as large as in a four-sheet Print: ——— But I shall change the Scene, and present you with something that will be still more agreeable. ——— It is a variegated Piece of Perspective, with many emblematical Scenes on a Landscape Ground: It is the Reverse of a Medal stamped on some extraordinary Occasion, though I cannot recollect particularly the Design.

Euphros. Be that as it will, it makes a noble Picture on the Side of the Room; and if these pellucid Pieces of miniature Drawings are capable of such high Improvement by the optical Science, it is hoped our *English* Artists will think of providing proper Subjects for our Entertainment this Way, in greater Plenty than we have hitherto had; since every curious Design of a picturesque Nature cannot fail of having that Effect. ——— But what do I now see! a wonderful Variety of mathematical Figures, Triangles, Circles, &c. in one Scene, and a Variety of figured Solids in the other; Pray, what is the Meaning of all this, *Cleonicus*?

Cleon. These were intended, my *Euphrosyne*, (not as a Subject of Entertainment this Way, but) as an artificial Help to the Memory of the young Mathematician; for on one Side of the Medal you have engraved, the Representation of the principal fundamental Theorems in Geometry, in a Variety of plain Surfaces; ——— On the other Side

Side the Medal are, finely engraved, a perspective View of the five *Platonic*, or regular Bodies; but as I intend these only to shew you what may be done in every Way where transparent Objects can be applied, even without the Assistance of Colours, I shall conclude, at present, with one Scene more, to shew how much these medallie Impressions may be improved and heightened by the Application of Colours.—Observe the splendid Appearance on the Wall.

Euphros. A glorious Sight, indeed; the King's Arms all richly blazoned and coloured, as the Laws of Heraldry direct.—I am, by this Time, thoroughly satisfied of the delightful Effects of this Instrument; and I am impatient to know how these Impressions are made, as it will be the highest Subject of Amusement for some of my leisure Time.

Cleon. It is a Solution of *Ising-glass* in Spirits properly prepared, which is not worth your while to attempt: I have provided for you a 4 Ounce Phial of this Substance, which you see has the Appearance of a fine white Glew, and will serve you not only for taking medallie Impressions, but also for many other useful and valuable Purposes.

Euphros. You will be so good as to let me see your practical Method of taking off Impressions first, and then I make no Doubt but I shall be able to do it myself.

Cleon. In the first Place, the Medal is supposed to be very clean; then, having dissolved the Glew by placing the Phial at a small Distance from the Fire, and placed the Medal very level on the Table, I pour the Glew on the Surface till it has covered the Whole, and with the Point of a Pin carry it nicely round upon the Edges of the Medal: I there let it stand to dry, or to evaporate the humid Part; the Remainder, which will be the pure Isinglass, will be so transparent as not to be seen on the Face of the Medal, and will, of itself, come off without giving you any Trouble in that Respect: And thus they appear, like those which you here see, of the Colour and Transparency of Glass.

Euphros. But how do you gild them with Gold and Silver, in that beautiful Manner of many of those Specimens before me?

Cleon. For that Purpose, I lay a Leaf of Gold or Silver on the Face of the Medal, and then pour the fluid

Glew upon it:——Or else, you may first pour on the Glew, and then let an expanded Leaf of Gold or Silver gently fall upon it, and thus the Impression will be gilt on the concave or convex Part: or you may put the Leaf of Gold on both Sides, and so gild it thoroughly: And thus they look like Gold or Silver Medals.——And I here present you with a Frame of such Gold Impressions, of all the Kings and Queens of *England* since the Conquest; together with the curious Devices on the Reverse of each particular Medal.

Euphros. I am infinitely obliged to you for these Instructions: I now can take what Variety of Impressions I please, and thereby enlarge and enrich my *Museum* of Curiosities at Pleasure.—But you was mentioning some other Uses that were to be made of this Solution; pray, what are they?

Cleon. They are of a more servile and inferior Nature, but still the best of their Kind; I mean, that of a gelatinous Substance, or Glew; for it is applicable not only where common Glew is, to cause a Cohesion in the highest Degree between Pieces of Wood; but in most other Substances that are liable to be broke, particularly those valuable Pieces of Furniture, Glass and China, when broken, will, by this Glew, be cemented so firmly together, that the Juncture of the Pieces will be hardly visible, and the Strength of it almost equal to that before it was broke.

Euphros. These are important Uses of the Glew, indeed; but, pray, how is it applied to produce the strongest Effect this Way?

Cleon. You must proceed thus: As soon as the Glass or China is broke, let each Part be placed by the Fire and made very hot, as also the Phial of Glew; then, with a Camel's-hair Brush, take a little of the Glew and strike over the fractured Surface of each Part, then carefully putting the Piece, or Pieces, into their proper Place, and gently pressing them together, let them stand till they are cold, and it will do admirably well for show, and, in many Cases, for real Use, as you will be thoroughly convinced of by every Experiment you try of this Kind*.

* It was thought necessary here to give a Representation of the several Instruments that have been described in some of the last

OPTICAL INSTRUMENTS.

Plate L.

Fig: I.

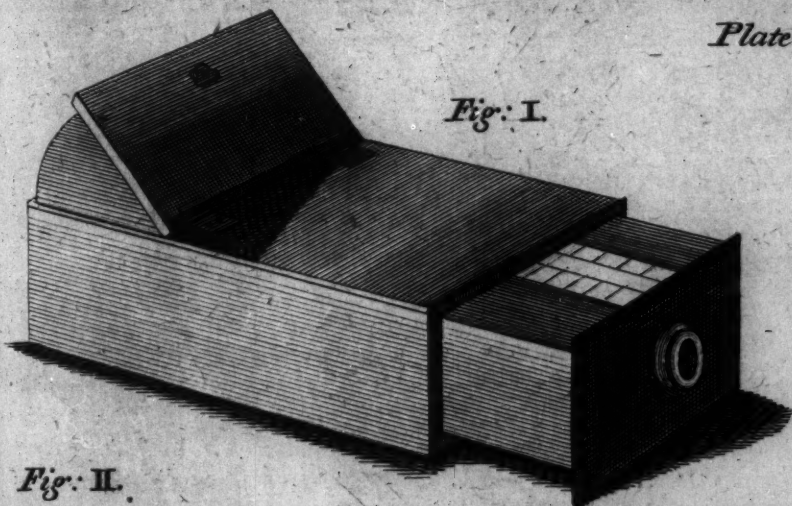


Fig: II.

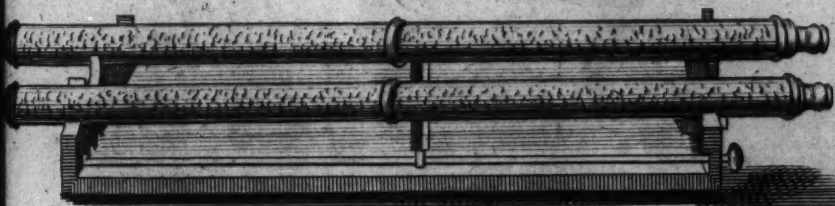
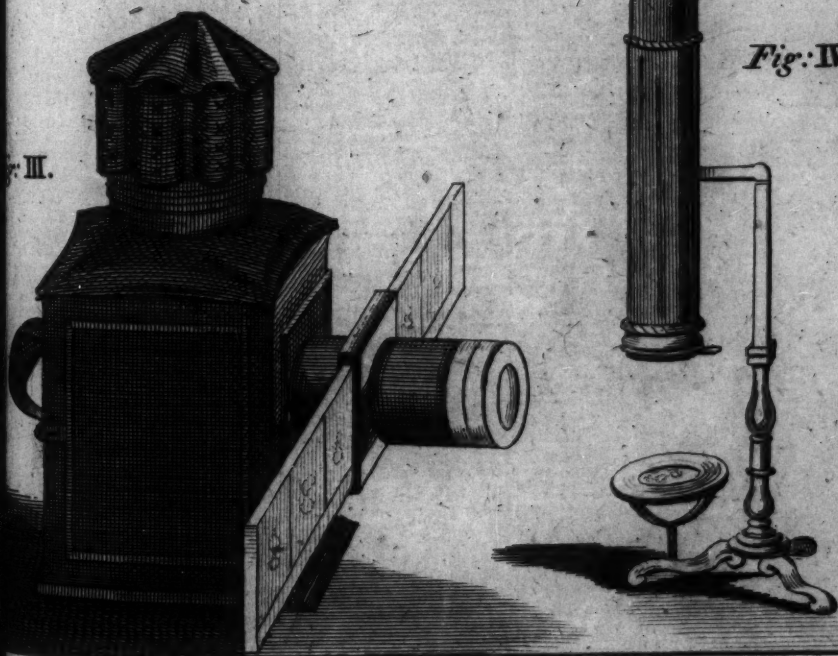


Fig: IV.





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P A R T VII.

DIALOGUE I.

The Description and Rationale of the optical OCTANT, and Helioſtata, or optical CLOCK.

Euphroſyne.

IT ſeems, *Cleonicus*, by the Apparatus you have prepared for my Entertainment at this Time, that you are going to quit the delightful Subject of Optics, for ſomething in the mechanical Way; for what elſe can be the Meaning of the Quadrant, Clock, and other mechanical Preparations I here ſee?

Cleon. The Subject of Optics is not ſo ſoon exhausted as you may imagine: This moſt delightful of all philoſophical Sciences affords you ſuch an extenſive Field, that you will find, that, as yet, we have little more than traверſed it half over, and that the remaining Part is all upon a delightful riſing Ground. The Objects of this Science are connected with, and depend, in many Reſpects, on the Principles of many others, particularly the

laſt Dialogues, that the Reader might have a more complete and ſatisfactory Idea of each of them: therefore, in Plate L.

Fig. I. Represents the portable and proportionable *Camera Obscura*, deſcribed at large in the 10th Dialogue of this Part, Page 250.

Fig. II. Is the refracting binocular Telescope, deſcribed in Dialogue 12, Page 270.

Fig. III. Is the optical Inſtrument, deſcribed in Dialogue 13, P. 274. It is here repreſented as placed on a Foot, or a Stand, for more convenient Uſe; but it will do very well without.

Fig. IV. Is the megalographic Lanthorn, above deſcribed. As the ſeveral Parts of theſe Inſtruments have been particularly deſcribed, nothing more need be ſaid of them here.

most useful Science of Mechanics; but I shall not propose any Thing for your Information that shall give you any Difficulty about understanding it.

Euphras. I shall never be tired in my Progress through these delightful Scenes: But I cannot say that I ever expected to meet with a Quadrant, or a Clock, in my Way among optical Subjects.

Cleon. Perhaps you might not; but it does not follow from thence, but that Quadrants, Clocks, and many other curious Inventions, may owe their essential Properties and Uses solely to the Principles of Optics, and yet never be the Subject of common Knowledge, or heard of by you or the Bulk of Mankind.—You will wonder, perhaps, if I tell you, that this very Quadrant (or, more properly, *Ostent*) has always been esteemed by those who are Judges as the most exquisite and useful of all the noble Inventions in Optics, which we owe to the great Sir *Isaac Newton*: And therefore, as such, I think it is very necessary that a Person of your delicate and general Taste for Science should be made acquainted with it.—I have often observed to you, that Science has no Relation to Sex, and therefore a Lady may as well be taught the Nature and Theory of *Hadley's* Quadrant, as that a Gentleman should be at the Pains of studying the Theory and Mechanism of a *Spinning-wheel*.*

Euphras. Whatever is of an optical Nature I am sure will please me, and therefore I shall very readily attend to all you have to say on that Instrument.—I see it is furnished with several Glasses, and therefore must be entitled to this Class:—I likewise observe a Speculum and a Telescope pertaining to your Clock, and therefore I consider it as a compound optical Machine.

Cleon. They are both of them strictly so, and the highest of the catoptrical Class; for all their Effects are purely by reflected Light, and the Principle on which they depend is of Course extremely easy, being only this, *viz. that the Angle of Incidence is ever equal to the Angle of Reflection*.—This Principle you have long since been taught the Truth of, by Experiment, and therefore must,

* See this domestic Machine explained, among others, in *Amerſon's Mechanics*.

at present, be taken for granted; and in this the whole Theory of these curious Instruments consists.

Euphras. If nothing more than that be required as a preliminary Qualification, I shall find myself very capable of understanding their *Rationale*, for there is not an Operation of Nature more familiar or easy of Demonstration, than the Principle you have now mentioned; and therefore you may proceed, as soon as you please, to its Application in the Construction of those Instruments.

Cleon. Preparatory to that, I have provided a little Machine to illustrate this Matter by Experiment: This consists, as you observe, of the following Parts, viz.

(1.) A reflecting Speculum or plain Glass, A B, moveable on a central Point C, through which passes a Wire, H E; and therefore at right Angles to the Plane of the Speculum. (2.) The

Wire H C is connected with an Arm H I, moveable about a Center I, so that, by the Motion of the Arm I H, the Wire H E, and

consequently the Glass A B, is moveable at Pleasure.

(3) On the Center I , with the Radius IC , you ob-

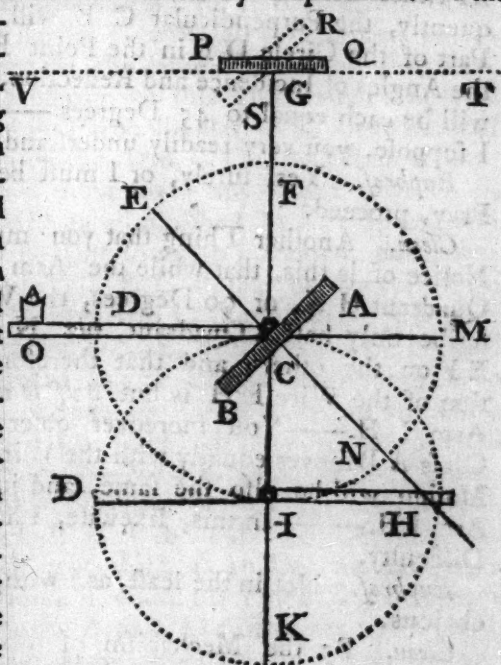
Center C, with the same Radius, is described the Circle

D F M I. (5.) You farther observe, that the Diameters

D M and L H are perpendicular to the Diameters F I and C K. (6.) In the Diameter D M, produced towards D,

EX. (6.) In the Diameter DM , produced towards D , I place a luminous Object, viz. the Flame of a Candle,

so that the Rays which come from it, and fall upon the
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Glass A B, will be reflected from thence in the Direction C F, making the Angle of Incidence D C E, equal to the Angle of Reflection E C F.—In all this, I presume, you understand me, *Euphrasyme*?

Euphros. With the utmost Ease, I can assure you. If there be nothing more difficult than this, you may proceed successfully.

Cleon. The next Thing you are to take Notice of is, that if the moveable Arm I H be placed at right Angles to C K, then will the Wire C H divide the Quadrant M I into two equal Parts in the Point N, and, consequently, the Perpendicular C E will bisect the opposite Part of the Circle D F in the Point E; in which Case the Angles of Incidence and Reflection, D C E and E C F, will be each equal to 45 Degrees.—This, likewise, I suppose, you very readily understand.

Euphros. Yes, surely, or I must be very dull indeed. Pray, proceed.

Cleon. Another Thing that you must take particular Notice of is this, that while the Arm I H describes the Quadrant H K, or 90 Degrees, the Wire E H will describe only half a Quadrant, viz. N I on one Part, and E F on the other; and that therefore the angular Motion of the Wire E H is but *half so much* as that of the Arm I H.—You moreover observe, that since the Glass A B moves equally with the Wire E C, its angular Motion will be also the same, and just half that of the Arm I H.—In this, likewise, I hope you will see no Difficulty.

Euphros. Not in the least, as I wish nothing to be more obvious.

Cleon. By the Mechanism of this Instrument, upon the Center C there is a moveable Arm C O, carrying the radiant Object, fixed upon it at O; and this Arm C O has the same Motion with the Arm I H, that is, when I turn the Winch you see the Arm I H move from H to K in the same Time that the Arm C O moves from D to F, and that the Glass and its Wire E H moves through half a Quadrant in the same Time.

Euphros. All this I observe with Pleasure, and understand with Ease. What follows next?

Cleon. I shall now show you the manner of using the Rays which come from it, and fall upon the

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Cleen. I turn the Winch backward, and bring the Arms I H and C O to their former Situation, perpendicular to F K; and you are then to take Notice, that a Ray of Light coming from the Candle at O, and from the Glass reflected to G, will there shew the Image of the Candle in another Looking-glass P Q, placed perpendicular to the Right-line F K. Now the great Point to be considered is, how, or in what Manner, the reflected Beam of Light C G is to be rendered permanent, or immoveable, while the Object at O is moveable upon the Arm C O, over the Arch D F; for if that can be done, the Candle in the Glass at G will, all that Time, remain quiescent, or be seen in the same Place; now this is effected by the Mechanism of this Instrument: because the Glass A B, and its Perpendicular E C, have but half the angular Motion of the Arm C O: And thus it happens, that while E C moves over any Space towards F, the Angle E C F will be diminished by that Space, and the Angle E C D be just so much increased, and, consequently, that the Angle E C F may be always equal to the Angle E C D, the Arm C O must move just twice as fast as the Perpendicular C E, or the Wire C H, and then will the reflected Ray of Light always continue in the same Position, or shew the Image at rest in the Glass P Q, while the Object or Candle is any where situated on the Arch D F.——For Example: If the Perpendicular moves from its Situation at 45 Degrees E to 50°, then will the Angle E C F be only 40 Degrees, and the Angle E C D 50, which is 10 Degrees more than the other: Therefore, if while the Point E describes 5 Degrees towards F, the Arm C O passes over 10 Degrees, it will all the while keep the Angles of Incidence and Reflection equal; and therefore the reflected Ray C G will be invariable, and shew the Image without any Motion in the Glass P Q.——The Truth of this you observe by Experiment, while I continue the Machine in Motion.

Euphros. It is very true; I see the Candle constantly moving over the Arch D F, while its Image appears perfectly at rest in the Glass P Q: A very curious Effect indeed, and such as I could not have thought producible from so easy a Principle.

Cleon. The next Thing you are to observe is, that since the Ray CG is, by this Means, fixed, it will be rendered so if reflected into any other Position: As, suppose GT parallel to OM , by moving the Glass PQ , on its Center G , into the Position RS , which is precisely parallel to that of the Glass AB , and then an Eye, placed at T , will see the Image of the Candle in the Glass RS at rest, as before, while the Candle moves over the Quadrant of a Circle from D to F .—I turn the Glass PQ into the Position RS , and you see, by Experiment, its Image continues immovable in the horizontal Line TV .

Euphras. All this is very evident, by Inspection.—I suppose I shall see the Use of it exemplified in the Construction of these Machines.

Cleon. You will, in many useful Instances:—But you are yet farther to observe that, for the same Reason, the reflected Ray is fixed, when the incident Ray is moveable. So, on the contrary, when the incident Ray is fixed, the reflected Ray will be moveable; for, if the Ray OC be supposed to continue the same, while the Glass AB and its Perpendicular AC be moved about the Center C , the Angle of Incidence ECD will be constantly altering, and since the Angle ECF must be always equal to it, therefore the reflected Ray CG must be constantly in Motion with a Velocity twice as great as that of the Perpendicular EC , or the Index CH , for the Reasons before mentioned. Therefore the Image will, in this Case, appear to be moveable, and which you see in every common Looking-glass, which, if you move them one Way or other, will always shew a Motion in the Images of Objects by Reflection.

Euphras. I never sit down to the Toilet without being obliged to observe this Phenomenon; but I never adverted to the Celerity of the Motion in those Images, or knew that it was twice as great as that of the Glass itself, which, by what you have now said, I clearly apprehend it to be.

Cleon. In the last Place you will observe, that when both the Glasses are equally moved together, the Perpendiculars to each Glass, as EC , GC , will constantly make the same Angle with each other; and therefore,

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also, the Angle of Incidence being ever equal to the Angle of Reflection, it will follow, that the incident Ray $O C$, and the second reflected Ray $G T$, will ever be parallel to each other; and, consequently, the Image at V always appearing in the Line $T V$, parallel to $O C$, must necessarily be quiescent, or motionless all the Time the two Glasses are in Motion: And this you will see by the Experiment ——— For observe, I move both the Glasses in the Instrument round the Center C , without altering their Positions to each other, and the Image of the Object at rest in O will appear to be at rest in the Glass $P Q$, to your Eye placed at K . — Again, I turn the Glass $P Q$ into the Position $R S$, parallel to $A B$, and then moving them both equally about the Center C , you will observe the Image, by the reflected Ray $G T$, at rest, in the same Manner as before.

Euphros. Your Instrument is very prettily adapted to shew these curious Particulars very naturally: But how is all this applicable to the Sea Quadrant, which, it seems, I must understand before I can pretend to be an expert female Navigator?

Cleon. When the Reason of a Thing is understood, the Practice can never be difficult: — This Quadrant, you see, which I take in my Hand, has the same two Glasses with those in this little Machine, the largest of which answers to the Glass $A B$, and is fixed upon an Index analogous to $C H$ in the Machine; the other Glass, on the Side of the Quadrant, is to be considered as fixed while the Quadrant is in use, and answers to the Glass $R S$: — Therefore, the Use of this Quadrant being to take the Height of the Sun at Sea, in a Ship continually in Motion (which would render the common Methods at Land impracticable there) this End is extremely well answered by the peculiar Property of this Octant; for, if I hold it up towards the Sun, the Rays reflected from the Index Glass to the other, will, upon moving the Index, shew a Motion of the Sun's Image in that other Glass: And, as one half only is silvered, the solar Image will in that be seen; and, in the unsilvered Part, the Horizon, or Edge of the Sea, will appear: And consequently, while you move the Index forward on the Limb of the Quadrant, you will observe the Image of the Sun to descend

scend in the Glas, till at Length it touches, with its lowest Limb, the horizontal Edge of the Sea: And when I have got it there, it will appear at rest, notwithstanding the Quadrant, or Glasses are moveable by the Motion of the Ship: The Navigator, therefore, has it in his Power to make this Contact as nicely as he pleases; and from what I shewed you before, the angular Motion of the Image of the Sun is twice as great as that of the Index of the Quadrant: And therefore I need only observe, that that Angle is expressed in the proper Degrees on the Limb, by reckoning every half Degree a whole one; for you observe, the Limb of the Quadrant is divided into 90 Degrees, whereas it is in Reality but 45, or the 8th Part of a Circle (for which Reason it is properly an *Octant*, and not a *Quadrant* :) And thus the Arch of the Sun's Altitude is, at any Time, very easily taken on the unsteady Basis of a Ship.

Euphros. I make no doubt but you can exemplify the Use of this Instrument by Moon-light, as well as that of the Sun: If so, there is now as delightful a clear Moon as you could wish.

Cleon. There is so: And I shall command the Queen of Night to descend, in Complaisance to you, from her lofty ætherial Seat, and be perched upon the Top of yonder Chimney, without any Power to move: or, to be serious, I will instantly measure her Height above that Chimney, which she seems to be perpendicular over. — Here, take the Quadrant, and hold it just in the Position as you see me do, and, looking through the small Hole in the Sight-Vane, you will perceive the Moon depressed to the Edge of the Chimney; and moving the Quadrant any how, you will observe the Image of the Moon to be as immoveable as the Chimney itself.

Euphros. I do, indeed; and so curious a Sight I never before beheld: For notwithstanding I move the Quadrant, or Glasses, the Moon appears as absolutely steady as if nailed on to the Top of the Chimney. — Now let me see the Number of Degrees on the Limb, — the *Vernier* cuts $27^{\circ} 30'$; that, I presume, is what you call the Height of the Moon above the Top of the Chimney?

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Cleon. It is: And after the same Manner you will find the Degrees contained in an Arch of the Heavens between the Moon and any particular Star, which is called the Distance of the Moon from the Star. Thus you observe yonder bright Star, called *Regulus*, or the Lion's Heart; the Distance of that Star from the Moon I easily find, by putting the Quadrant into a proper Position for bringing the Reflection of the Star upon the quicksilvered Part of the small Glass, and then I move the Index till I bring the Image of the Star to touch the Limb of the Moon next to it, and then you will observe the curious Appearance they make both together:—Here, take the Quadrant, and put it into the same Position for your own Eye.

Euphros. This I will do as soon as I can:—I find it requires a little Practice to be ready at this Matter:—I have just now brought it to bear, and see the Star nicely touch the Limb of the Moon next to it.—This is a very pretty Phænomenon, indeed.

Cleon. On the Limb, you observe, the Index has moved over 23 Divisions, which is therefore the Number of Degrees contained in the Arch of a great Circle, between the Moon and the Star: And to measure this Distance of a Star or the Sun from the Moon, is a principal, and most useful Problem in Navigation, and was the original grand Design of this Invention, by Sir *Isaac Newton*.

Euphros. You have thoroughly convinced me of the important Uses of this valuable optical Instrument:—But I imagine, since you can so readily measure the Arch of Distance between any two Objects, it must be of Use in many Cases on Land, as well as at Sea: Is it not, *Cleonicus*?

Cleon. You may think it very strange, that a Person should be able, by any Instrument whatever, to take the Height of the Sun, or any other Object, in a Ship rolling on the Waves of the Sea, more certainly, than on the firmest Footing by Land: But you will soon recollect, that at Sea there is sometimes a clear and evident HORIZON, from which we can measure the Height of the Sun, Moon, or Star; but, on Land, such an Horizon is wanting, and therefore this excellent Instrument is but
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of little use in the common Construction: But it is yet capable of an *artificial Horizon* being adapted to it, and thereby the Altitude of the Sun may be observed, not only by Land, but likewise at Sea in foggy Weather, when the Sun, but no Horizon, can be seen: By this Means also, it may be rendered of very great Use in *Surveying*, and in all Cases where a *Theodolite*, *Circumferentor*, or common *Quadrants* are applicable.

This new Construction of a Quadrant I shall take some other Opportunity of giving you a farther Insight into, having said, at present, as much as I thought necessary, to give you a general Idea of this noble Invention, as it pertains to the Class of *optical Instruments*.*

DIALOGUE II.

The Description and Use of the HELIOSTAT, or the solstitial and planetary CLOCK, on a new Construction, for fixing the SUN, MOON, and PLANETS in astronomical OBSERVATIONS.

Cleonicus.

I Have reserved this Opportunity as the most convenient, for instructing you in the Knowledge of the Nature and Use of an Instrument, whose Theory is the most sublime of all in Philosophy. This grand Invention, like all others, has arrived at its present Perfection by several Gradations. Its first Principle is founded in Optics, and its general Nature is derived from optical, mechanical, and astronomical Principles; and this you will easily conceive when I tell you, that it is a Clock of such a peculiar Nature, as to fix the Rays of Light from any radiant Object, and thereby to render the Sun Beams of Use in the *Camera Obscura* more perfectly than any

* It was not judged necessary to exhibit, in a Plate, any Thing relating to the Structure or Uses of the Quadrant, as that is fully done in a small Treatise, which is given with every Instrument of this Kind that is sold.

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Instrument has hitherto done ; and also, what is still of much greater Consequence, the Astronomer can hereby detain the Sun, Moon, or Planet, in his Telescope, in a quiescent State ; by which means they become the proper Subjects of his Observation, and that for any Time proposed. This hath been hitherto the *Desideratum* of Astronomy ; for as often as the Astronomer has been intent upon determining the Eclipses of the Sun and Moon, upon delineating their *Maculae*, or Spots, or measuring their apparent Diameters with a Micrometer, so often he could wish to say, *Sun, stand thou still ; and Thou, Moon, proceed no farther in thy Path* : Since the constant Motion of those Luminaries, in the Telescopes, does every Moment elude his utmost Efforts to accomplish the above mentioned Designs.

Euphros. Well, and are those great Points effected now by this new Clock, which I here observe in so elegant a Construction ?

Cleon. They are, in a Degree superior to any Thing that could be expected in so complicated a Machine, and fully sufficient to answer all the Intentions of the most accurate Astronomer.——It may seem very strange, that though it be wholly impossible to stop the Sun in its Course, yet that it should be so easy to fix, as it were, his Rays, and thereby render him apparently motionless : But nothing has been so arduous and paradoxical, which Philosophers have not, at one Time or other, endeavoured to effect, and often have found, to their great Satisfaction, and to the Perfection of the Sciences, that they are far less so in Fact than in Appearance.—The first Step towards the Discovery of this universal, optical, and astronomical Clock, was the Invention of Sir *Isaac Newton*, in regard to fixing the Image of the Sun, by two Reflections from two Speculums in *Hadley's Quadrant*, as I explained to you in the last Conversation : and since it appeared, from the Experiment in the small Machine you then saw, that the Beam of Light from a moveable Object was rendered stable by one Reflection, and of Consequence the Image was thereby rendered quiescent, or at rest, by a Reflection of that fixed Ray, it was easy to conclude, that if Rays, thus fixed by a first Reflection, could be thrown upon the Object glass

of a Telescope, by Reflection from a second Speculum, then might the Image of the Object be made to appear at Rest through such a Telescope, and this was soon found to be practicable, by Experiment : But then they found a constant manual Operation was necessary, to keep the first Speculum moving, so as always to keep the reflected Rays in one and the same Position in the Telescope.—— Thus far went the illustrious Inventor himself here in *England*, and the celebrated *Fahrenheit* and *Bessai*, abroad.

Euphros. This seems to be a large Step taken at once; but, pray, what was the next Enterprize, to render this Machine more perfect?

Cleon. The next Improvement was an Addition of *Clock-work*, by the late learned *s'Gravesande*, who, in a most superb Manner, constructed one of these Machines, by which the solar Beams, reflected from a single Speculum, were rendered permanent, and consequently fit for all Experiments of the *Camera Obscura*, and all the Purposes of telescopic and astronomical Observation.

Euphros. No doubt but such an Atchievement in the Sciences was received with great Eagerness and Applause: I suppose, those who had Occasion for trying Experiments on Prisms, the solar Microscope, &c. took the first Opportunity of availing themselves of this Invention, and that no public or private Observatory would be without such a telescopic Clock.

Cleon. Alas! my *Euphrosyne*, it is much to be wished, the Fate of the Sciences were not so much like that of Virtue itself, *viz. to languish under universal Applause*: For notwithstanding the Philosopher had, by this Means, rendered the Sun obedient to all their Wills, and fixed him for their View for every Kind of Observation, yet have I never heard of a Purchaser of one of those noble Machines, nor have I conversed with any Gentleman who had ever so much as seen them. I thought it would reflect great Dishonour for such an Invention not to be found in any *English* Author, and therefore procured a Copper-plate of it to be engraved and published, to gratify such *English* Artists who might be willing to enquire into its Nature and Uses; and this, as far as I

can

* The
Britannica

can learn, is the only Appearance it has ever made in England*.

Euphras. But I see you have now proceeded farther, and constructed such a Clock in Reality: Pray, is this the same as you mentioned before of *s'Gravesande*, or is it with any additional Improvement since?

Cleon. It has received several Additions from the celebrated Philosopher and Mechanic C. G. KRATZENSTEIN at *Petersburg*, who has rendered its Construction more universal, by adapting it to the Motion of the Planets, as well as that of the Sun, to which *s'Gravesande* was confined, together with some other Alterations and Improvements, which render the Use of it more simple and easy: But even the Accounts which this Gentleman has given of the Machine, in the Commentaries of the *imperial Academy of Sciences*, is such as left sufficient Room for many Alterations to be made even in his new Construction. These I have attempted in the best Manner I could think of, and which makes the Appearance of the Clock as here exhibited to your View; and I can think of nothing more that can be altered, or added to it, to render it more fit for use.

Euphras. As this Machine promises so much Ease, with Exactness, in astronomical Observations, I suppose those Machines that have been heretofore used for such Purposes will now be laid aside, unless the Expence should be any Objection to this new Improvement.

Cleon. The Expence is so far from being an Objection against it, that it is a very great Circumstance in its Favour; it is designed to succeed what is usually called the *equatorial Telescope*, which, by a large and complicated System of Wheel-work, puts it in our Power to find out the heavenly Bodies very readily, and to continue them in the Field of the Telescope, by a constant Application of the Hand to the several Screws; by this Means, the Astronomer can make a Shift to keep the Planet in View, but not to fix it there, which was the great Point wanting, and effected only by this new astronomical Clock: And

* The Plate here referred to is to be seen in the *Philosophia Britannica*, at the End of the Lecture on Optics.

yet, after all, the equatorial Telescope will cost more than double the Price of this Machine.

Euphros. If the Advantages of this be so much greater, and the Expence so considerably less, I should think there can be no question made of its being readily received, and greatly encouraged here.—I suppose, by what you say, that which I here see is the first that has been made in England?

Cleon. It is; and an *Automaton* of this Kind is a new Phenomenon in the King of Great Britain's Dominions. The Ingenuity of Clock-makers has hitherto principally appeared in shewing, besides the Hour of the Day, the Age and Phases of the Moon, the Day of the Month, the Equation of Time, and some other Particulars of that Sort, which were judged to be useful or necessary in domestic Affairs: But, in regard to the Sciences, very little has hitherto been effected by Clock-work; the great Point endeavoured by the principal Mechanics in this Way is an *equable Motion*, which is almost as impossible in its own Nature as a *perpetual Motion*, both on Account of the Nature of the Materials of which such Machinery must consist, and also from the Principles of Mechanism themselves. However, great Sums of Money have been expended for improving Machines only to approximate thereto, it would be incredible were I to mention the exorbitant Sums that have been paid for Clocks and Pendulums on this Account; and yet, after all, we find no such Thing as an equable Motion in any tolerable Degree †. Those Pieces called Regulators, as the Machinery is the most simple, so their Motions are most equable; but even those very Automata themselves require to be regulated by sydereal Observations, and every Clock hitherto proposed is confined to the *mean solar Time*: But the Clock we are now to discourse of is of an universal Nature, and shews, as well the *Lunar* and *Planetary* Days as that of the Sun, by the Contrivance of a Pendulum proper for such a Design.

† *N. B.* I have lately constructed a *TABLE-CLOCK*, with a half-second Pendulum, of an invariable Length, going 8 Days, of which see a farther Account in a Treatise given with the Clock.

Euphros. I have not a clear Idea of what you mean by a lunar or planetary Day: Pray, *Cleonicus*, explain that Matter to me, that I may understand the Use of your Machine in its full Extent?

Cleon. That I will do, as such a Phraseology is not as yet very common; and, for this Purpose, I shall distinguish Days into four Kinds, (1.) A *sidereal Day* is that Space of Time which is taken up in one complete Revolution of the Earth upon its Axis, or, in other Words, the Time that passes from the Moment in which any particular Star is on the Meridian, to the Moment it returns to that Meridian again. (2.) A *solar Day* is the Time that passes from the Sun's leaving the Meridian, to its Return thither again: This Day we usually divide into 24 Hours. (3.) The *lunar Day* is the Time which intervenes between the Moon's Departure from the Meridian, and her Appulse to it again. (4.) A *planetary Day* is the Time which the Planets severally take in departing from, and returning to the same Meridian.—These several Sorts of Days are of a very different Length from each other, and the three last constantly variable among themselves; especially those of the Moon and Planets: And as the Design of this Clock is to stop the apparent Motion of these Luminaries, it is necessary the Index of the Clock should be adapted to a Motion analogous to those of the heavenly Bodies themselves, which is effected by a Pendulum of a different Structure from any that has yet been made, as none of the common Sort would commodiously answer this End.

Euphros. Then, if I apprehend you right, when you purpose to observe the Sun, you adapt the Pendulum for moving the Index in such a Manner as to shew *solar Time*, or the 24 Hours of the common Day.—— But how do you proceed with regard to the *Moon* and *Planets*?

Cleon. As the lunar Days are almost an Hour longer than the solar Day, the Pendulum must be made to vibrate slower, so that the Index, or Hand of the Clock may be made to go once round in about 25, instead of 24 Hours; for the longer the Time is of the diurnal Revolution, the slower the Pendulum must move of Course, that the Hand of the Clock may correspond to

the Motion of the Planet. Thus, for Instance, the longest lunar Day is almost exactly 25 Hours, and therefore, if I make the Vibration of the Pendulum slower, in the Proportion of 25 to 24, the Index of the Clock will keep Time with the Moon for that Day, in such Manner, that were you to observe the Moon through the Telescope, by the Rays of Light reflected into it from the Speculum of the Clock, she would appear fixed, or immoveable in the Field of View, and you would have the utmost Pleasure of viewing her variegated Face without any Interruption from her Motion; of which signal Curiosity, I shall give you a remarkable Instance, by-and-by, by Way of Experiment, after we have refreshed ourselves at the Tea-table.——But as for the Planets, their Motions are, some slower, and others quicker than that of the Sun; their Days will therefore be, in Proportion, shorter or longer than the *solar Day*. Thus, for Example, suppose *Saturn* upon the Meridian, together with the Sun, this Day at Noon, then, as the Motion of *Saturn* is slower than that of the Earth, in its Orbit, or Sun in the Heavens, the Earth, in revolving upon its Axis, will sooner bring the same Meridian to *Saturn*, than to the Sun; and, therefore, when I shew you that Planet through the Telescope of the Machine, in order that he may remain quiescent in the View, it will be necessary for me to accelerate the Motion of the Pendulum in Proportion, as the *Saturnian Day* is shorter than that of the *Solar One*. On the other Hand, if it be proposed to view the Planet *Mercury*, as his diurnal Motion in his Orbit exceeds that of the Sun, then, if I retard the Motion of the Pendulum in such Proportion as the *mercurial Day* exceeds the Length of the *solar Day*, will you have a View of this Planet fixed, or permanent as if really motionless in the Heavens. And this Procedure is the same with regard to any of the other Planets; and this is called, *rectifying the Machine for planetary Observations*.

Euphros. I suppose it will also require to be rectified for the Latitude of the Place, since I perceive your Clock is not in a perpendicular Position, like other Clocks; but inclined to the Horizon in a certain Angle.

Cleon. It is true; the Face or Plane of the Clock must ever be parallel to that of the Equator, and therefore inclined, in the same Angle, to the Horizon; and consequently the Clock must be rectified to the Latitude of the Place where it is used; on which Account, the Fulciment, or Supporter at the End of the Hour-Index, which carries and directs the Index of the Speculum, must also be longer, or shorter, in Proportion, as the Latitude is greater or less; for otherwise, if this be not scrupulously observed, the Luminary will not appear fixed in the Telescope.

Euphros. I farther imagine, by another Part of your Apparatus for the Speculum, that that also must be rectified, or adjusted to the Sun's Declination at different Times of the Year.

Cleon. In this you also conjecture right; for, according to the different Declination of the Sun, North or South of the Equator, so the Speculum must consequently have its Height above, and Distance from the Clock properly altered: To which End, you observe, a due Provision is made by Sliding bars, which are adjusted, by Screws, to a great Exactness in each of these Respects; and because the Declination of the Moon and Planets, from the Equator, never exceed $30^{\circ} 0$, it was not necessary to provide for viewing any Objects beyond that.

Euphros. Do you not likewise find it necessary to adjust the Machine, in regard to the Meridian and Horizon?

Cleon. Yes: These are also Articles to be nicely observed; and in order thereto, you take Notice of a curious *magnetical* NEEDLE and COMPASS placed in a proper Part of the Machine, by which it is placed due North and South:—And then, with regard to his horizontal Position, you see there are two Spirit levels placed at Right-angles to each other, by Means of which, and four adjusting Screws, the Machine in all its Parts is truly placed in a horizontal Position. These Things are all of them easy to be performed for any given Time, as is evident by Inspection.

Euphros. But, as the Speculum has its Height constantly varying above the Base of the Machine, it seems necessary that the Telescope should always keep Pace with it, or be elevated, or depressed, exactly in the

same Degree : To which Purpose, I see the same Contrivance applied by Sliding-Plates and adjusting-Screws, for fixing it in the required Position.—If there be any farther Particulars relating to its Rectification, you will be kind enough to mention them, as I am impatient to see the Effects of so requisite and uncommon a Machine.

Cleon. Nothing remains now but to rectify the Machine, and shew you the Use of it, which, at present, must be confined to the Sun : We have just now half an Hour for that Purpose.—To this End, it will be only necessary to put to the Window-shutters, and let a Beam of the Light come through a Hole, made in one of them of a sufficient Width, that it may, for some Time together, fall upon the reflecting Speculum.—This you see is done, and the Sun-beam is reflected in a Position parallel to the Floor, and falls on the Side of the Room, which reflected Beam you will observe continues immoveable, or always retains the same Position or Direction.

Euphros. To prove this, I must make a Mark with my Pencil in the Side of the luminous Spot, and then I can easily observe if it moves or not.—A sufficient Time has passed to have observed the Motion, if there was any :—By this Time I am fully convinced that the reflected Beam is perfectly quiescent :—It is not without some Degree of Surprize, and equal Pleasure, that I observe this new and very extraordinary Phænomenon, *a Beam of Light fixed and motionless!*

Cleon. It must afford the highest Satisfaction to every *Virtuoso* in Optics, to have the solar Beam transmitted into his Room, and there, by this Means, rendered constant and immoveable, for Hours together, without the least Trouble to himself ; while he may sit down, and, at his Pleasure, apply his Prisms in all the Variety of Experiments relative to the different Refrangibility, Reflexibility, and Colours of Light : Also, his solar Microscope, for magnifying small Objects, may here be applied without that expensive Apparatus that usually attends them, the *Wilson's* Part only being here sufficient for all such Purposes ; especially if, instead of the plain Speculum which you now see applied to the Clock, one considerably concave was placed in its Stead ; for then would the Rays of Light be reflected converging to a
Focus,

Focus, and in this converging State, *Wilson's* Microscope might easily be applied, on a proper Foot or Stand, and all Experiments thereby performed with the utmost Ease.

Euphros This I plainly perceive; and many other Uses I make no Doubt but such a permanent Beam of Light, in its various Forms of parallel, diverging, and converging Rays, may be made to answer, by those who are curious in this Science ——— But I want to have a View of the Sun through the Telescope, which I observe you have taken off from the Machine.

Cleon. I will replace it, and adjust it, that you may say, for once, you have seen the Sun without Motion. — There, look through it.

Euphros. I behold the glorious Orb, which nearly fills the Field of View: — And there I see it remains without the least Tendency to Motion: ——— With how much Pleasure, now, I view the Spots on the several Parts of his Disk, and their relative Positions: I have now an undisturbed View of every Part of that wonderful Body, which I never beheld in any such Perfection before: — It gives me great Pleasure and Delight, to see the *Sun stand still* by such a plain and simple Contrivance of Art: — One would wonder, that a Thing so very curious in its Nature, and yet so very plain and easy in itself, should not long ere now have been found out.

Cleon. There seems to be, for the continual Entertainment of Mankind, a gradual Discovery both in the Works of Nature and Art. It is not consistent with the Notions we ought to form of a wise Providence, that it should at once open all the Scenes of Knowledge to the Views of Mankind: This would rather confound and perplex, than instruct and amuse them; and it appears, by Experience, that every Age, before it can be thoroughly instructed in the Doctrines of former Times, has a great Variety of Novelty to excite and exercise the Ingenuity of Men. — But to return: You have seen the Sun itself quiescent through the Telescope; you will, in the next Place, be no less pleased to see the Image of this great Luminary transmitted through the Telescope on the Side of the Room, as soon as you remove from your Place. — I move the Screw on the Side of the Telescope

scope but a little, and you see the solar Disk, with all its Spots, depicted on the Side of the Room, as motionless as a Picture in a Frame : You may there draw the Circle and delineate all the Spots, and thus make a Map of the Sun with Ease and Pleasure.

Euphros. This is a most curious Effect indeed, and one of the most sublime Experiments I have hitherto seen : ———The Sun itself, the Beam, the Image, the Spots, are all, by this Means, permanent and fixed, and, consequently, must thereby give the highest Satisfaction in all curious Enquiries of Nature, and answer the utmost Expectations of Astronomers. ———But now let us adjourn to Tea : I am persuaded by this Time, you stand in Need of some Refreshment. —

Cleon. I promised you, as soon as it became dark, to entertain you with a View of the Moon and the Planet *Jupiter*, through this horological Telescope, and we have now a most delightful Opportunity for that Purpose : —The Evening is very clear and mild, and the Moon and Planet present themselves fairly to the View.

Euphros. We could not have wished for an Evening more serene : —But your Machine, I presume, will want adjusting before I can have the Pleasure of any lunar Aspects through it. You told me the lunar Day was longer than that of the Sun, and that therefore the Pendulum must vibrate slower to adjust the Clock to lunar Time.

Cleon. This is previously necessary to be done ; for, by the Nature of this Pendulum, the Clock may be adjusted to any Sort of Time without altering its Length, or the Use of any secondary Bob or Ball to be screwed up and down, as in common Pendulums : —I have set it now to the Time of the present lunar Day : —I find, by the *Ephemeris*, that the Moon will culminate this Night, or be upon the Meridian at three Minutes after XI, therefore I move the Hour-circle about till such Time the common XII o'Clock Line cuts that Hour and Minute : —Thus is the Hour circle adjusted for the Moon. —Then I place the Hour-Index to the present Moment of Time, which is half an Hour after VII. —Lastly, I adjust the Speculum to the Moon's Declination, and placing the Machine due North and South, you will find

find the lunar Rays, reflected from the Speculum into the Telescope, will present you with the Phases of that nocturnal Luminary without any Interruption from its Motion.—You may now replace yourself in your Chair and view them.

Euphros. 'Tis delightful, thus to set at my Ease and view the bespangled Face of the Moon as long as I chuse:—I have now nothing to do but to feast my Eyes with that wonderful Variety which there appears: I have often viewed her dark and brighter Spots, but never had so clear an Idea of all together as now presents itself in this steady and uninterrupted View.—It seems all one, as if I viewed a real Map of the Moon drawn with infinite Art and Perfection.—As I understand, pretty well, the Rules of Drawing, I could find no Difficulty in making an exact Copy of this celestial Prototype:—Which brings to my Mind, how often I have wished that such a Thing as this could be rendered feasible, that we might have the Pleasure of viewing the Moon in an adequate Representation, or a Natural Map thereof, as I am fully convinced nothing of that Kind, of seven or eight that I have hitherto seen, can any how deserve that Title, or be esteemed a tolerable Copy of the Moon.

Cleon. What you observe is with too much Reason; the World abounds with Maps of the Moon, and some of the Sun; but they who made the latter, one would naturally think were born blind; at least, it could never be supposed they had ever seen the Face of the Sun thro' a Telescope, as there cannot well be a greater Difference between the uniformly smooth and glowing Face of the Sun, decorated only with a few small Spots, and that shocking Representation thereof by Father Kircher, full of Flames and Vulcanos.—It is too easy a Matter to view the Face of the Moon in a common Telescope, not to be able to make some Resemblance of her; but still it is evident, from all the Maps of the Moon I have hitherto seen, that Resemblance is so distant, and so imperfect, as to be scarcely allowed to be called a Portrait of the Lineaments and native Beauties of her Face.—In short, our *Selenography* is the most imperfect Part of all our Astronomy; But you see, by this Machine, how

easy

easy it is to make an exact Draught of the Moon, even just as easy as to take a Copy of any Family Piece placed on the Easel before you. Nay, even those who have no Skill in Drawing, by Means of a proper Lattice of Squares placed in the Focus of this Telescope, might, in this Manner, be able to make an accurate Map of the Moon.

Euphros. This noble Invention makes all the Difficulty of constructing a just Map of the Moon vanish, as here is nothing to divert or interrupt his Pencil or his Fancy.—But I shall be too tedious, therefore hasten to shew me the Planet; for I consider that you have done, as it were, double Duty this Day, and that you will not be a little fatigued.

Cleon. Never fear me, my *Euphrosyne*: Why should not I be able to talk two Hours, as well as some of your Sex a whole Day together.——But now for the Planet: the Scene must be altered, the *Jovian* Day is shorter than that of the Sun, and therefore the Pendulum must now be adjusted to beat Time to *Jupiter*:—Also, the Speculum must be adapted to its Declination from the Equator; and as he was upon the Meridian at VII o’Clock this Evening, and it is now just turned of VIII, therefore I bring the Hour of VII to the Meridian Line of the Clock, and place the Hour-hand to the present Minute after VIII, and thus is the whole Machine, in all its Parts, adjusted to view the Planet, undisturbed by the Motion of the Earth about its Axis, or his own real Motion in his Orbit:——As such you may now view it.

Euphros. I view him in perfect Serenity and Rest:——A charming View of his spacious Disk regales my Sight:——I see three of his Moons with great Distinctness; but one of them is either eclipsed or suffers an Occultation.——He continues still in the same Part of the Field.——This must, surely, give a fair Opportunity for observing the Eclipses and Occultations of these Satellites, and consequently for discovering the Longitude, which, I have often heard you say, is more feasilby by this Method than by any other.

Cleon. Your Observation is very just: This Clock will be of singular Benefit to Mankind in that Particular; since,

since, in whatever Part of the World it is used, the Longitude of that Place will be hereby discovered with the utmost Ease and Certainty.—In short, from the Nature of the Thing, it is most evident, that no astronomical Observations can be made with Ease and Exactness by any other Means than this, which will be sufficient to recommend it to all the Studious in natural Science, as an Object of the greatest Curiosity and Utility to Mankind.—Having thus given you a particular Account of all the useful Constructions of optical Instruments, I shall endeavour to prepare you, at the next Opportunity for perceiving the infinite Wisdom in the Construction of the Organ of Sight, or Vision, in the natural Mechanism of the Eye, by a few previous Speculations on the Nature and Effects of single Glasses or Lenses.

DIALOGUE III.

On the NATURE and USES of SINGLE LENSES, both Convex and Concave, applied as READING-GLASSES, VISUAL-GLASSES, and BURNING-GLASSES.

Euphrosyne.

IT gives me the greatest Pleasure to find we are approaching towards an Enquiry into the natural Constitution and Mechanism of the Eye, which you propose to explain to me, by a Dissection of the same, and a particular Account in what Manner every Part is conducive to so noble an End:—But you tell me, I must be previously acquainted with the Use of single Glasses, the better to comprehend the same; and accordingly I see you have a great Variety of convex and concave Lenses, Spectacles, &c. spread before me on the Table.

Glean. I have provided such an Assortment only as will be necessary for you to know the Uses of, as Reading-Glasses, or such as assist the Sight by a single Application of them to the Eye.—But here I do not suppose

you are ignorant of the Nature of a convex Glass in general, or of its Uses in the Construction of optical Instruments, which I have exemplified to you in so many Cases. — You very well know, that if an Object be placed on one Side of such a Lens, at more than its focal Distance from it, the Rays, proceeding from every Point, diverging upon the Glass, will be refracted through it, converging to so many Points on the other Side, which form the Image thereof. — You have also been taught, that when an Object is placed just at the focal Distance of the Lens, the Rays will then be refracted parallel to each other, and thereby fitted to produce distinct Vision of such an Object: This you had an Instance of in those very small Lenses which are used in single Microscopes: — But there is one Case yet remaining, in which both convex and concave Lenses become extremely useful to Mankind, which has not yet been explained: And that is, when the Object is placed between the focal Point and the Glass itself.

Euphros. This Case is indeed new to me, and I should be very much pleased to know in what Manner these Glasses are rendered serviceable to us in this Respect. — When an Image is formed of an Object, by a Lens, I can easily conceive how that Object may be contemplated in its Image; — also, I know, that when an Object is placed in the Focus of a Lens, it becomes in itself thereby visible; — but when it is placed nearer to the Glass than its Focus, I have no Idea which Way the Object becomes magnified to the Sight.

Cleon. Yet this you must understand before you can be properly said to know the Theory, or *Rationale* of a common Reading glass, which, you know by Experience, has a magnifying Power, and may be as properly called a *Megascopes* for magnifying large Objects, as very small Lenses are called *Microscopes* for magnifying small ones. Thus, the Page of a small printed Book may, in itself, be considered as a large Object, while the Words and Letters are too small to be easily read by a good Eye, and not at all by one whose Sight is rendered in any Degree deficient by Age, or other Accidents: But when a large Convex Glass, in this Case, is applied between the Book and the Eye, the Page becomes greatly dilated to the View, and

and the small Characters appear as a large and easily legible Print.

Euphros. All this I know very well, as I am oftentimes obliged, in case of such very small Prints, to make Use of a Reading glass myself; but how this magnifying Power is produced, I am still at a Loss to apprehend, and must beg of you to explain.

Cleon. This I will do in the best Manner I can; but it must be by a Diagram, as no real Image of an Object is, in this Case, formed any where but in the Eye: To this End, therefore, let ECD be such a Reading-glass, or Convex Lens, and let F be the Focus in the Axis FN ; on C the Center of the Lens, with the Distance CF , describe the Arch of a Circle QFP , draw the right Lines QC and PC , making any Angle with the Axis FC on either Side; then, in the Line QC , let any Point, A , be taken, and from that Point let the Lines AE , and AD be drawn, to represent two diverging Rays issuing from that Point on the Convex Glass. Now, you know, it is the Property of a Convex Lens to bring diverging Rays, which fall upon it, nearer after Refraction, and therefore the Rays AD and AE , instead of pursuing their first Directions to I and L , will, by the Lens, be refracted nearer together, viz into the Direction DK and EM :—If then these Lines DK and EM , as they are inclined to each other, be continued out, they will meet in a Point G in the Line QC . All this, I suppose, is very plain from the Figure, my *Euphrosyne*.

Euphros. So very plain, that it can admit of no farther Explication. But what am I to infer from thence?

Cleon. This much, that the Point A , being not far from the focal Distance Q , will cause the diverging Rays AI and AL , after Refraction into DK and EM , to be not much different from *parallel Rays*, and therefore will produce distinct Vision of the said Point A :—But then the apparent Place of the Point A will be much altered; for since the two refracted Parts DK and EM enter the Eye, as if they came from the Point G , they will there represent the Point A ; so that the apparent Distance of that Point will be much greater than the real Distance CA . This, I suppose, you can likewise see from the Diagram?

Euphros. Nothing is more evident; and at the same Time I observe, from your Drawing, that on the other Side of the Axis the Rays proceeding from the Point B will, after Refraction, represent that Point at H.

Cleon. Your Inference is just; and I see, by that, you have a clear Idea in what Manner the Points A and B are removed to the Distances G and H respectively from the Glass; and that therefore all the Space contained between A and B will be expanded into the Length, or Space contained between G and H; and consequently any Objects contained between A and B will be enlarged in Appearance, in the Proportion of the Distance between A B to the Distance between G H, that is, in the Ratio of A C to G C: and consequently, if the Page of a small printed Book be placed at the Distance of A C from the Glass, and parallel to it, the Words, or Print of that Page, will appear enlarged in the same Proportion as G C is larger than A C, with respect to their Diameters or lineal Dimensions: But the whole Area, or Surface of the Page, will be enlarged or magnified in Proportion as the Square of A C is to the Square of G C.

Euphros. This I see very plainly illustrated by the Words, *God save the King*, in small Print between A B, and in much larger Characters between G H.—Pray, *Cleonicus*, is there any general Rule to be observed, for holding the Reading-glass, with Respect to the Eye and the Print?

Cleon. There is, my *Euphrosyne*:——For by the Mathematical Theory we learn this Rule, *the Distance of the Object A C and that of its magnified Appearance G C, is always in the Proportion of the Distance of the Object from the Focus A Q, to the Distance Q C of that Focus from the Glass*; and, consequently, from hence you will observe, the less A Q is, or the nearer the Object is held to the Focus of the Glass, the more it will be magnified; and since the Rays passing through the Glass differ but little from parallel Rays, it will give a distinct View of the Object so magnified; and by moving the Glass one Way or the other ever so little, you will immediately find the Position of the Object, and the Glass where the Field of View and magnifying Power will best suit the Eye. But this is a Point which we are directed to by Nature,

Nature, without any Rules of Art. And this, I think, is as much as I can say with regard to the Nature and Use of a READING-GLASS.

Euphros. Is there nothing particular with respect to the Size, or focal Length of those Glasses, by which we may be directed in the Choice of them?

Cleon. Yes, most certainly; for if it be proposed to read with both the Eyes, then, in such a Case, the Glass must be sufficiently large to transmit the Rays from the Object to both the Eyes, and, consequently, ought not to be less than three Inches in Diameter: ——— The elliptic Form is also preferable to a round one, in a Reading glass: ——— and, lastly, the longer the focal Distance, the less irksome is the Effect to the Eye. But in this Respect, the Eye must be consulted, and the magnifying Power of the Glass must be such as is required.

Euphros. What is the Difference between these large Reading-glasses and Spectacles, or *Visual Glasses*, as you call them.

Cleon. The Nature and Effect of both are much the same, only the Visual Glasses, being disposed in a proper Frame, may be, in different Ways, applied to the Eye, without being held in the Hand; and, therefore, leaving both Hands at Liberty, they are much better suited to all Occasions of Reading, Writing, Working, &c. than a manual Glass can be. ——— Besides, the Vision is more distinct and perfect through two Glasses, than by one alone; because the Axis of each Glass, when they are properly fixed in their Frames, may be made to coincide with the Axis of each Eye respectively; and therefore the Rays of every Visual Pencil will be much more naturally refracted to the Eye, than they can be through a single Glass, where only the collateral Rays of such Pencils can enter the Eye, by which the Vision can be neither so easy or perfect as in the former Case.

Euphros. But what is the Reason of this black Circle or Ring of Horn about the Glass?

Cleon. There is more Reason for this than many Persons are aware of: the Pupil of the Eye is but small, and no more Light can be of Service to Vision, than what

enters that Pupil : a Spectacle-glass, therefore, but little bigger than the Pupil of the Eye, would be sufficient for converging a Pencil of Rays to the Eye as large as that which now enters it from the widest Glass ; therefore all that Part of a Pencil, so very large, as falls on such a Wide Glass, must, by far the greatest Part, be lost upon the Eye : but that is not the worst Consequence of a broad Glass ; the great Quantity of Light which falls upon the Ball of the Eye cannot fail, by such a constant Suffusion, to disturb and render Vision indistinct, by that which really enters the Eye : not only so, but the constant Action of Light upon the Ball of the Eye must have a sensible Effect, in Time, in weakening the same, and produce, gradually, those Changes and Alterations in its Texture as must be attended with Uneasiness to the Person, and injurious to all the Purposes of Vision.——Therefore, to prevent, as much as possible, such bad Effects, the circular Zone, or Ring of Horn is applied on the Out-side of the Glass, to cut off so much of the collateral Rays, or hurtful Part of Light : and were this Rim broader, and of Course the Glass narrower, it would still conduce more to the Perfection of Vision : But as there is no Convenience without an Inconvenience, the making the Glass narrower would be apt to contract the Field of View too much ; the Diameter, therefore of the Glass must be left so large as will admit of a sufficient Extent of View, for all the Purposes required ; and all that is more, is detrimental, and ought to be excluded.

Euphros. I have no Occasion, as yet, to experiment the Truths you have been now advancing ; but I judge of their Reasonableness from the Structure of optical Instruments, and from the Make of the Eye itself ; for in all Microscopes, Telescopes, &c. I observe a Diaphragm, or Stop is placed in the Focus of the Eye-glass, to circumscribe the View within proper Limits : And also, the Apertures of Object Lenses adjusted to a peculiar and determinate Size, for Admission of one requisite Degree of Light, in order to produce distinct Vision in those Instruments : And I make no Doubt that the same Reason holds, for the small Size of the Aperture, or Pupil of the Eye itself :——But as I shall, at other Times,

discourse with you farther on this Subject, you will give me Leave to ask one Question concerning *concave Lenses*: How they become so useful to short-sighted People, as I find they are useful to them only?

Cleon. The Nature and Use of those Lenses will be better understood; after you have seen a Dissection of the Eye; and then the Uses of these, and also of Convex Glasses, will be exemplified with Experiments of an *artificial Eye*.

Euphros. Are there any other considerable Uses to be made of convex; or concave Lenses?

Cleon. There is one of a very extraordinary Nature, viz. the *Power of BURNING*, which is the Effect of very large convex Lenses, and concave Speculums; this they perform by converging the Sun's Rays into a very small Space, or into what we may properly call the solar Spot, or Image of the Sun: And it is well known the smaller the Space is into which a given Quantity of Rays can be collected, the more dense they will be, and consequently the more powerfully they will act or burn.

Euphros. I have heard much concerning the wonderful Effects of Glasses of this Kind, with Respect to their burning Power; but have seen little or nothing of it more than the common Experiment of lighting a Pipe, or making a Piece of Wood smoak with a common Burning-glass.

Cleon. These are trifling Effects to what are producible by these Kind of Glasses. But as I know you will not be satisfied with the mere Relation of Facts, though of ever so wonderful a Nature, without some previous Ideas of the Reason and Cause of them, and, as in this Case, it is not very difficult to be understood, I shall give you the following concise *Rationale* thereof:—

You have seen that every Object has its Image formed by a convex Lens, and concave Mirror, in its Focus; accordingly, the Sun itself will have its Image produced of a sensible Magnitude, because, as I have formerly told you, the Object and its Image subtend equal Angles at the Glasses; and therefore, because the Angle under which the Diameter of the Sun appears is full half a Degree, therefore, also, the Image of the Sun will

subtend an Angle of half a Degree at the Glass :—Had the Sun been at an infinite Distance, it could have subtended no sensible Angle at all, and its Image would have been a Point in the Focus of the Glass ; but that is not the Case ; for, in the Focus of all Glasses, the solar Spot, or Image, is of a sensible Magnitude, and may be measured and compared with the Area of the Glass itself.

Euphros. If I understand you right, all the Rays which fall upon the Surface of the Glass are collected into that circular, and very luminous Spot, which we call its Focus, and then the Rays of Light will be denser in that Spot, in Proportion, as the Surface of the said Spot is less than the Surface of the Glass ; and, consequently, their Disposition to burning.—But what will be the most convenient Method of measuring this solar Spot ?

Cleon. You may very readily hold a Box-ruler, divided into Inches and Tenths, and thereby estimate the Diameter of the solar Spot in Tenths of an Inch : But this Method will not do in all Cases, I shall therefore propose one that will.—It happens very luckily, that, with the Radius or Distance of six Inches, one Degree is very nearly equal to $\frac{1}{16}$ of an Inch ; therefore, at the focal Distance of 12 Inches, half a Degree will be equal to $\frac{1}{8}$ of an Inch, or that will be the Diameter of the solar Spot of a Lens whose focal Distance is 12 Inches.—Now this Spot in a Lens of twice, or three Times that focal Distance, will be twice or three Times as large ; so that in a Lens of four Foot Focus, it will be $\frac{1}{2}$ of an Inch, and so on for other Lengths in Proportion.

Euphros. This I clearly apprehend ; but what is your Inference from hence ?

Cleon. When the Diameters of the Glass and solar Spot are known, then also the Proportion of their Surfaces are known, being always in Proportion as the Squares of those Diameters. Thus, for Instance, if a Lens be four Inches in Diameter, and its focal Distance 12 Inches, then will the Diameter of the Spot be $\frac{1}{8}$ of an Inch, as I said before : But in the Diameter of the Glass there are $\frac{1}{8}$ of an Inch, therefore the Area of the solar Spot will be the Area or Surface of the Glass,

as

as the Square of one to the Square of 40; that is, as one to 1600: Therefore the Density of the Sun-beams, in the solar Focus, will be 1600 Times greater than that of the solar Rays falling upon the Glass: And hence you may plainly perceive the Reason why a Lens no more than 4 Inches in Diameter will yet prove so powerful a Burning-glass, as you observed it in the Instances you just now mentioned.

Euphros. I now begin to see plainly the Reason of the Effects of Lenses and Mirrors, in regard to burning; and I also apprehend, that this Power of burning will increase in Proportion to the Square of the Diameter of the Glass, while the focal Distance remains the same.

Cleon. It will so: Thus, suppose the forementioned Glass of 12 Inches focal Distance, were 6 Inches, or $\frac{1}{2}$ of an Inch, in Diameter, then will its Power of burning be to the former as 3600 to 1600, or more than twice as great, because more than twice the Quantity of Rays fall upon this larger Glass.

Euphros. But supposing the Surface of the Glass continue the same, but has a less focal Distance, then will the solar Spot be likewise less; and, consequently, the same Quantity of Rays being collected into a smaller Space, will act, or burn more vehemently: Therefore, also, the Power of burning must be greater in Proportion as the Area of the solar Spot is less. Is not this right, *Cleonicus*?

Cleon. Extremely so: You reason like a Mathematician.——The true *Ratio* is, the Diameter of the solar Spot being always as the focal Distance, the Area thereof will be as the Square of its Diameter, and consequently as the Square of the focal Distance of the Glass: Therefore we collect this general Rule, *the Power of burning in any Lens is proportioned to the Square of its Diameter directly, and the Square of its focal Distance inversely*: And from hence it will be very easy to compare the burning Powers of any Lenses whose Diameters and focal Distances differ.

Euphros Pray, what are the largest Size Lenses usually made for this Purpose?

Cleon. They seldom exceed 7 or 8 Inches in Diameter; and are from 3 to 4 Feet Focus; and such a one you here see: The Diameter of this is 8 Inches, and the

Focus 3 Feet distant, therefore the solar Image will be $\frac{1}{8}$ of an Inch Diameter: And, as there are $\frac{80}{9}$ of an Inch in the Diameter of the Glass, it will condense the Rays in Proportion, as the Square of 80 to the Square of 3, that is, as 6400 to 9, which is little more than 700 to 1. Whereas I observed to you before, that the Power of a common Burning-glass, no more than half this in Diameter, and whose focal Distance is but $\frac{1}{3}$, had a Power of burning as 1600 to 1, which is more than twice as great as this very large Lens is capable of, which Instance I give to satisfy you, that as much may be done by shortening the Focus of the Lens as by increasing its Diameter or Surface.—But, when the Diameter of the Lens is very large, it will require a very extraordinary Thickness of Glass for grinding them to a short focal Distance, sufficient to render them burning-glasses in any considerable Degree.

Euphros. But, pray, *Cleonicus*, is there no Method of combining two of these Lenses together, to increase their Power of burning?

Cleon. Yes, my *Euphrosyne*, there is; for if a Lens of 6 Inches Diameter and one Foot focal Distance, and another Glass 4 Inches Diameter and 6 Inches focal Distance, were put together at a proper Distance, the Rays of the Sun, collected to a Focus by them, would be more dense, and burn more powerfully than they could be made to do by any single Lens:—But there is nothing of this Kind that can compare with a concave Mirror in this Respect; for, in these Mirrors, the solar focal Distance is never more than half the Radius of Concavity; and what still adds to the Intensity of their burning is, that the Aberration of the Rays, in the Focus, arising from the Figure in the Glass, is not near so great as in the Focus of a Lens of the same focal Distance in Diameter.

Euphros. Since concave Speculums are in their own Nature so well fitted for Burning-glasses, I presume, the Ingenuity of Philosophers must have been exercised in various Ways, to render this Invention as extensive and powerful in its Effects as they possibly could.

Cleon. No Pains has been spared, by ingenious Artists in the optical Way, for constructing these burning Speculums

culums of different Kinds, of which I shall mention to you four of the principal Forms. The (1) is an entire concave Glass, but of very large Diameter, and as short a focal Distance as possible. (2.) A very large spherically concave Frame, in which are placed several lesser concave Speculums, of the same Radius with that of the Frame: These, truly fixed, will have all their Focuses thrown upon one common Focus in the Axis of the Frame, which, of Course, must burn to a prodigious Degree. (3.) In such a large Frame, they have also contrived to fix plain Glass Speculums, which, being duly adjusted by Screws, will throw all the Sun's Rays which fall upon them into one common Part of the Axis of the Concave Frame, which, there making a Sort of Focus, will burn very intensely. (4) Any large concave Frame, as before has been described, with a smooth polished Surface of such Matter as will strongly reflect the Rays of Light, and has been found to answer extremely well.

Euphros. Have you seen those several Kinds of Speculums which you now mention?

Cleon. I have seen of the first and second Sort; but never any of the third and fourth: ———But of the first Sort, I have never seen any so large as to deserve particular Mention at this Time: Those of 2 Feet, or 2 Feet and $\frac{1}{2}$ in Diameter, are the largest that are commonly made, and are much more used for optical Purposes than for Burning-glasses, as their focal Distances are not short enough to answer the Purpose of burning so much as might be expected from so large a Surface: However, all of this Kind, that are in any Degree large, burn very intensely, especially with a Summer Sun.

Euphros. And what have you known of the second Form of Speculums, which you mention; which, I think, may be called compound Burning-glasses?

Cleon. They are very properly such; but all that I know of them is, that they have been made of a very large Size, one of which, in particular, contained about 30 very large square concave Speculums, not less than 20 by 24 Inches, if I remember right: This very large concave Speculum was placed at the Top of a House, viz. at the great Toy-shop the Corner of St. Paul's

Church-yard, moveable upon an Axis, to render it of more convenient Use: But as to its Effects, though they must have been incredibly great, I do not remember to have had any particular Account of them, any more than in one Instance, *viz.* that a large Bar of Iron would instantly be melted asunder in its Focus.

Euphros. That was a prodigious Effect, indeed; and I wonder very much, that the World has not been more apprized of the stupendous Effects of a Concave burning Speculum of such an amazing Structure. — Pray, what do you know of the third Sort you mentioned, compounded of plain Speculums instead of concave ones?

Cleon. This is but a late Invention; the principal Instrument of this Sort was made by Mr. *Buffon*, which was 6 Feet in Diameter, and contained 168 small Mirrors, or flat Pieces of Looking-glass, with proper Movements for adjusting them to a common Focus: They were each of them 6 Inches square. — But what is peculiar to this Contrivance is, that we have it in our Power to make the focal Distance greater or less, and, consequently while the Frame remains in the same Place the Glasses may be so adjusted and disposed as to throw their common Focus upon the Object intended for Accension.

Euphros. This must be a curious Artifice most certainly; but I suppose the Difficulty and Expence of such an Apparatus, for this Purpose, is not inconsiderable: — But, pray, has it been brought to any great Perfection, or has any very considerable Experiments been made with it?

Cleon. It is said, that Mr. *Buffon*, in the Month of *March*, set on Fire Boards of Beach-wood, at the Distance of 150 Feet: At another Time he burnt Wood at the Distance of 200 Feet: He also melted Tin and Lead, at the Distance of 120 Feet; and Silver, at 50. — But, as you rightly judge, the Expence of such a compound Speculum must be very great, since each small Speculum had no less than three adjusting Screws to give it a proper Inclination, for directing the solar Rays to any given Point, and the whole Machine is moveable by a Swivel-like Contrivance; so that one may burn horizontally, upwards, or downwards, and that almost at any Distance one pleases.

Euphros. One would think such an Instrument as this should prove dangerous, especially near the Sea-side, were Ships in the Harbour might be liable to be set on Fire by it.

Cleon. Your Observation is so far rational, that, if such a Machine could be conveniently made, it would certainly be of Use to every Town liable to a Siege, whether by Sea or Land, especially if the Time for adjusting the Lenses were not very tedious. It is related by several Historians, that ARCHIMEDES did actually set Fire to the Roman Fleet, at the Siege of *Syracuse*, by a Burning-glass; and that the Navy besieging *Byzantium* was, by a Burning-glass under the Direction of PROCLUS, reduced to Ashes. But what Sort of Glasses the Ancients made Use of for this Purpose, Historians do not inform us; but, very probably, they were not Speculums, but either Lenses or burning Spheres.

Euphros. Then you really think that Burning-glasses, of some Sort or other, were in Use among the Ancients? Pray, what Account do you find of them among the Writers of Antiquity?

Cleon. I can say but little on that Head: *Pliny* mentions what he calls Balls, or Globes of Glass and Crystal, which were made Use of by Surgeons, who collected the Sun-beams with them in order to cauterize their Patients: And *Lactantius* tells us, that a Glass Globe, filled with Water and held up to the Sun, would kindle a Fire even in very cold Weather: But, to pass by other Instances, there is one very remarkable in the first Scene of the second Act of *Aristophanes's* Play, called *The Clouds*, which the famous Mr. *De la Hire* makes no Doubt is a full and convincing Proof of the Use of Lenses, as Burning-glasses, among the Ancients; and, because the Passage is not long, I shall read it to you out of that Author: — *Strepsiades*, an old stupid Fellow, tells *Socrates*, he had found out an excellent Contrivance against paying his Debts; and is introduced speaking after this Manner:

STREPSIADES. Have you never seen, at the Apothecaries, that fine transparent Stone with which they kindle Fire?

SOCRATES. Do you mean that Glass?

STREPSIADES. *Yes.*

SOCRATES. *Bring it; what then?*

STREPSIADES. *When the Attorney hath written an Action against me, I will take this Glass, and, standing at a Distance in this Manner against the Sun, I will melt down the Letters of my Action.*

SOCRATES. *Cunningly done, by the Graces.*

The Scholiast upon this Place says, this Glass was a *Trochoide*, which implies, that it was round like a *Wheel*, and, therefore I think very plainly indicates its being of a lenticular Form, and not a complete *Globe*.

Euphros. Well, this has pretty well gratified my historical Curiosity:—Tell me next, what you know of the fourth Kind of Burning-glasses.

Cleon. With respect to the Power of Burning, they are the most celebrated of any, concerning which, we have several curious Anecdotes; for Mr. *Boyle* made one of these, of black Marble, of a very large Size; but, though well polished, yet, being of a black Colour, it would not set Fire even to Wood, though exposed a long Time in its Focus; which plainly shews how small a Quantity of Light is reflected from black Substances. —On the other Hand, we read of a Burning-glass (if we may so call it) that was made only of a smooth Concave Surface, and overlaid, or finneered, as it were, with white Straw, made by an *Italian* Artist, which had a prodigious Effect in burning from the Light reflected from so large a Surface and natural polish of Straw. —But the most remarkable of all these Sorts of Mirrors was that of the celebrated Mr. *Villette*, which was 3 Feet 11 Inches in Diameter, and its focal Distance was 3 Feet and 2 Inches: It was a Composition of Tin, Copper, and Bismuth, somewhat like the Metals we now make for reflecting Telescopes; it was a white Metal, and bore a very fine Polish, and therefore, from so large a Surface and so short a focal Distance, it is no Wonder if we find its Power of burning, melting, calcining, and vitrifying Bodies very extraordinary indeed.

Euphros. I wish I could get Information what some of those Effects might be, for I have a great Inclination to be satisfied about every Thing in regard to the *Wonderful*.

Cleon. In this you are not particular, my *Euphrosyne*; it is a Kind of universal Passion that, more or less, affects all Mankind; Things of an uncommon and extraordinary Nature never fail to strike us with agreeable Pleasure and Surprise: And as Burning is in itself one of the most exquisite Actions of Nature, the following Experiments, made in Relation thereto, cannot but give you the highest Satisfaction: A Catalogue of such as are most remarkable I shall here rehearse to you.

1. A red Piece of *Roman Patera* (or Tile) began to melt in 3", and was ready to drop in 100".

2. Another black Piece melted at 4", and was ready to drop at 64".

3. Chalk taken out of an *Echinus Spartagus* fled away in 33".

4. A Fossile-shell calcined in 7".

5. A Piece of *Pompey's Pillar* at *Alexandria* vitrified in the black Part in 50", and in the white Part in 54".

6. Copper Ore vitrified in 8".

7. Slag, or Cinder, of ancient Iron-work, ready to run in 29 $\frac{1}{2}$ ".

8. Iron Ore fled at first, but melted in 24".

9. Talc began to calcine at 40", and held in the Focus 64".

10. *Calculus humanus* was calcined in 2", and only dropped off in 60".

11. A great Fish's Tooth melted in 32 $\frac{1}{2}$ ".

12. The Asbestos seemed a little condensed in 28", and Mr. *Villette* says, the Glass usually calcines it.

13. Marcasite of Gold broke to Pieces, and began to melt in about 30".

14. A Silver Six-pence melted in 7 $\frac{1}{2}$ ".

15. A Copper Half-penny (of King *William's*) melted in 20", and ran with a Hole in 30".

16. A King *George's* Ditto, melted in 16, and ran in 34".

17. Tin melted in 3".

18. Cast-Iron melted in 16".

19. Slate melted in 3", and had a Hole in 6".

20. Thin Tile melted in 4", had a Hole, and was vitrified in 80".

21. Bone calcined in 4", and was vitrified in 33".

22. A Diamond, weighing 4 Grains, lost $\frac{7}{8}$ of its Weight.

Euphros. These are wonderful Effects indeed, to think that the *Asbestos* itself, which no common Fire can injure, should yield to the calcining Force of this Burning-glass.—I suppose you have the same Method of computing the Force of this Glass, as before of the Lenses?

Cleon. The very same; and by Computation it appears, that the solar Beams are condensed by this Speculum upwards of 17,000 Times, and that the Heat in the Focus of this Glass will burn with Intensity 433 Times greater than that of common Fire; and therefore nothing is an *Asbestos*, *Amianthus*, or *incombustible* Substance in the Focus of such a Speculum.—It may be in my Power one Time or other, to repeat these Experiments, and verify them by ocular Demonstration; but, at present, you must be content with a mere Narration of Facts.

DIALOGUE IV.

The NATURE and STRUCTURE of the EYE explained, with regard to perfect VISION, by an anatomical DISSECTION thereof.

Cleonicus.

OF all our Sensations, those of Vision have been ever esteemed of the first Order: It will therefore be no unpleasing Speculation to my *Euphrosyne*, to be entertained with a short Narrative and Explication of the natural Mechanism of the wonderful ORGAN of SIGHT, and what the proper Office of each constituent Part is, or how far it conduces to perfect this most exquisite of all our Senses.

Euphros. I am transported with the Thoughts of being in any Degree capable of understanding the Principles upon which the Structure of so noble an Organ depends; the component Parts of the Eye, I presume, you

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The Nature of VISION explained.

Plate LI.

Fig. 4.

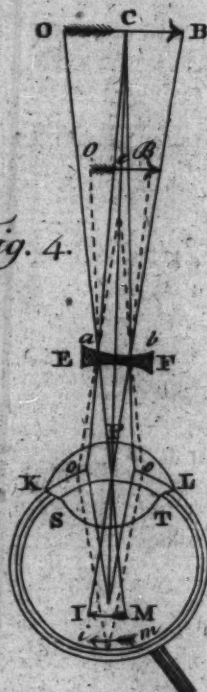


Fig. 3.

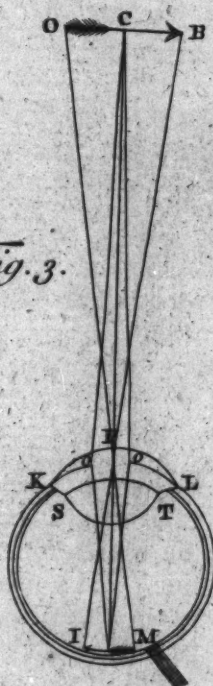


Fig. 5.

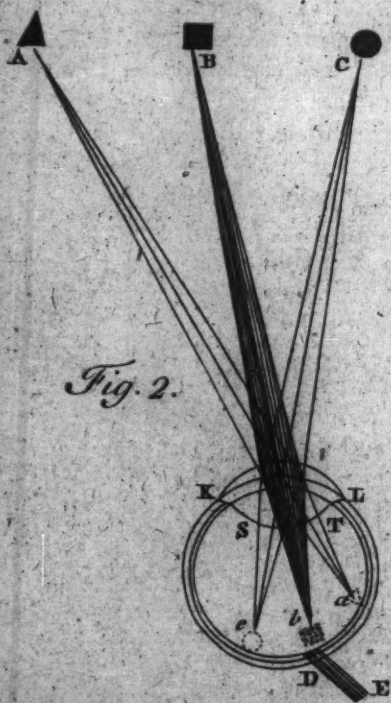
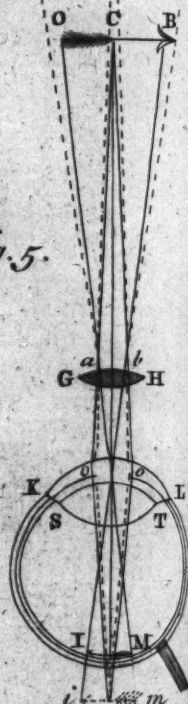


Fig. 2.

God save the King

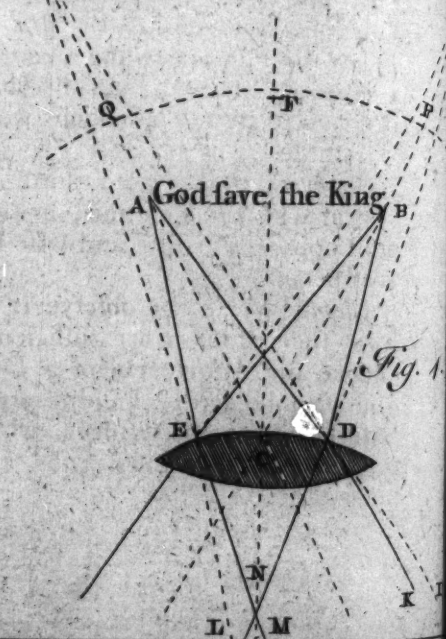


Fig. 1.

you intend to exhibit, by a Dissection of those Eyes which I see you have here prepared; and, as I have never yet seen any Thing of this Kind, the Instructions I shall receive will be both novel and improving in the highest Degree.

Cleon. I do not propose to trouble you with an anatomical Account of the great and wonderful Apparatus of Muscles, wherewith the Eye is furnished for all necessary and convenient Motions; this being only a collateral Consideration, or Circumstance of the principal Object we are at present intent upon, which is the Faculty of natural Vision: For though the Eyes of many smaller Kinds of Animals, as in most of the insect Tribes, are fixed, yet they are so disposed, that Motion in them is rendered unnecessary, as they can see all around them without: But as the Eyes of most Animals, and particularly our own Species, are both in Front, and we could look only directly before us, provided there was no muscular Motion, it became necessary to construct the Eye with a Variety of Muscles to give it Motion, in all Directions, in the visible Hemisphere before us; and one Thing I must not omit to observe, that as it is sometimes necessary to have an oblique Motion of the Eye towards the Nose, and there being no Room on that Side for Muscles, as on every other Part, provident Nature (which is never at a Loss for Means to accomplish her Designs) has contrived a small Bone on the Side of the Nose, with a small Perforation, or Hole to serve as a Pulley through which the Tendon of a Muscle passes to a convenient Insertion, and thereby such an oblique Motion is given to the Eye, which would have been otherwise impossible.

Euphras. One would think it was impossible that any Person who considers this, or any such Instances of the most apparent Design and wise Disposition of Parts, could ever be an Atheist.

Cleon. What you observe is very just; they who consider such Things are sufficiently convinced of the Existence and Providence of a Deity; and perhaps there is not a more fertile Field of irrefragable Proofs of those wise Designs and Artifices, which Nature makes Use of to answer her proposed Ends, than anatomical Dissections.
Every

Every Part in the Structure of animal Bodies fills us with Wonder and Amazement, not more at the Almighty Power, which is visible, in making, but at the infinite Wisdom, which is so manifestly employed for answering, in the best Manner, all the Purposes of the animal Oeconomy.—But now to the Point: You see, here are two Bullock's Eyes, which I have provided on purpose to dissect, that you may see how far the several Parts are concerned in producing the sublime Faculty of Sight: —But, before we begin the Dissection, it will be worth your while to consider a few Particulars, respecting the external Disposition, or Form of the Eye: And first of all, you observe a long white cylindrical Body of nervous Fibres, which enters the Eye on the hinder Part or Bottom of the Eye, and which the Anatomists usually call the OPTIC NERVE.

Euphros. The Part you now mention has engaged my Attention ever since I have been in the Room; but before we proceed farther, pray let me know what you mean by NERVE.

Cleon. A Nerve is that most distinguished Part of animal Bodies which Naturalists tell us is the universal Organ of Sensation. A Vegetable is an organized Body, and has Variety of Vessels for circulating Fluids analogous to those we find in animal Bodies called Arteries, Veins, &c. but, as it has no Sensation, there is no Occasion for this Part which is called the *Nerve* and therefore we find none in the *vegetable* SYSTEM.

Euphros. But, pray, *Cleonicus*, how is this Part, you call a Nerve, the Organ of Sensation?

Cleon. I can give you but a partial and imperfect Answer to such a Question.—The Nerve, which you see, is a Continuation of the medullary Substance of the Brain, contained in proper Coats, or Integuments; the Fibres of this Nerve having passed through the Coats of the Eye, are there spread into a most exquisite fine Membrane, which covers all the interior Parts of the Eye, except that which is open before: This Membrane the Anatomists call the *Retina*, and is, beyond all Dispute, the immediate Instrument of Vision:—For the Rays of Light which enter through the fore Part of the Eye, being refracted to this nervous Membrane,

will

will so affect, by their various Impulse, the Fibres thereof, which are in immediate Connection with the Brain, as to convey to the common Sensory thereof the Species of Things without us, from whence they proceed; and by this Means they excite in the Mind the Ideas of those Objects under all their Circumstances of Form, Magnitude, Distance, Colour, and all their other Affections.

——But how, by this natural Agency of one Sort of Matter upon another, those mental Ideas are formed, and the Operations of the Mind directed and influenced, is a Subject far beyond the Reach of the human Understanding.

Euphros. I know the inscrutable Secrets of Nature do not belong to us: I think myself very happy that I have the Faculty of Vision, though I can never adequately know the wonderful Manner in which it is effected; it is enough for me that I can be acquainted with the Ways and Means which the Author of Nature makes use of to effect it.——But I observe, *Cleonicus*, that the optic Nerve enters the Eye on one Side, and not directly in the Middle of the Bottom of the Eye; pray do you assign any Reason for that?

Cleon. Yes, my *Euphrosyne*, and a very good one too, viz. because the Rays of Light, which fall on that Part of the Eye where the Nerve enters it, are thereby rendered of no Effect, or become useless in that Point, where all the Fibres of the Optic Nerve are divided one from the other, and no one in particular can be acted upon by those Rays:——By this Means you will easily understand that those Rays which come from Objects quite on one Side of the Hemisphere of View can be lost; but those Rays which are lost in one Eye, are always effectual in the other: So that with both the Eyes, it is in our Power to see every Object wherever posited in the natural Extent of View.——Hence another Instance offers of wise Contrivance, as also a Reason, among many others, why two Eyes are naturally of more Advantage than one.

Euphros. By what you have said, one would conclude, that an Object could not be seen by Rays which fall on that Part of the Eye where the Nerve enters it: Pray, is there any Experiment by which this can be confirmed?

Cleon. Yes, there is, and which you shall immediately try, for your own Conviction.——I will stick three Pieces of Paper (A, B, C) * upon the Side of the Room, about 15 Inches apart, and then I will place you at such a Distance from, and directly before the middle Paper, that if you shut one Eye, and then turn the other obliquely towards that outside Paper, which is on the Side of the enclosed Eye, the Rays coming from the middle Paper (B) will enter the Eye, and fall upon the Insertion of the optic Nerve, by which Means the said Paper will immediately vanish from the Sight, while the two extreme Papers continue visible.

Euphras. This is such an optical Paradox, that I long to be satisfied of the Truth of it by Experiment——I see you have placed the Papers on an advantageous Ground to be viewed:——But now, whereabouts must I stand to view this odd, or rather *No Phenomenon*?

Cleon. As the Papers are about 15 Inches asunder, you must place yourself directly before the middle Paper, at the Distance of about 6 Feet and a Half, and take Care that your Head be not in the least turned on one Side:——Then shut the left Eye, and turn the right Eye obliquely to view the left Hand Paper (A), and the middle Paper, (B) will instantly disappear at the same Time as the other extreme Paper (C) is visible.

Euphras. Well, I think I am very near the Spot you point to, and that my Face is quite parallel with the Side of the Room:——I shut my left Eye, and direct my Right to the left Hand Paper, without moving my Head:——And, sure enough, the middle Paper is gone; it disappears as if by Enchantment,——and the other Paper beyond is still in my View.——I think this Experiment equally curious as wonderful.——But now, let me try with the other Eye.——I find it the very same as before; therefore to each Eye, in this Situation, the middle Paper becomes invisible, though so large as an Inch Square.

Cleon. Nor is there only that particular Spot on which you stand, where this will happen: But if you remove yourself

* See Fig. 2. Plate LI,

yourself through the Space of 10 Inches back, in a Right-line, you will observe the same Thing, or the Paper will continue unseen through all that Space; for so long will the Image (*b*) of that middle Paper be passing over the Place where the Nerve (*DE*) enters the Eye, while the Images (*a* and *c*) of the two extreme Papers are at a considerable Distance from that Point, and therefore constantly visible to either Eye.

Euphros. This is a striking Instance of Contrivance, indeed: But pray, what have you farther to observe in Relation to the exterior Parts of the Eye?

Cleon. The Form of the Eye on the posterior Part deserves your Notice: It is neither plain, nor spherically round, as I have heretofore observed to you that neither of these Surfaces will admit of a perfect Representation of the Images of Objects, portrayed in the Focus of a Glass: But it is really of that Form which the Laws of Optics require for a perfect Delineation of the Images of Objects, as well in an oblique, as a direct View, on the Expansion of the optic Nerve, or *Retina* in the Eye.

Euphros. This is a curious Circumstance, most certainly, and is very obvious with the slightest Inspection. — I see all the back Part of the Eye is opake, and the fore Part only is transparent.

Cleon. This will convince you of the Truth of that which I have often observed to you, *viz.* that the Eye is nothing more than a most perfect *Camera Obscura* in Miniature, in which the whole Business of Vision is transacted; for which Purpose you see, on the fore Part, a very transparent and convex Covering, which is called the *Cornea*, or *horny Coat* of the Eye (*L P K*, Fig. 3.)

Euphros. I think I can see the Reason why it is both transparent and convex; for the Transparency is necessary to a free Admission and Refraction of Light, and the Convexity of it is necessary for converging the Rays of Light to a Focus, at the Bottom of the Eye, for the Formation of Images there: — And one Thing farther I can hence observe, and that is, the proper Degree of Convexity in the Eye, which must ever correspond to the Diameter or Bulk of the Eye; since the

optic Nerve, in the Bottom of the Eye, must necessarily be in the Focus of the Convex *Cornea*, as you call it. But, pray, how is the Convexity of this Part supported, and constantly kept up?

Cleon. By a fine limpid Humour, which lies immediately under it, and, being in Appearance like *Water*, is called the *Aqueous*, or watery Humour of the Eye. — This you will be immediately sensible of; for I pierce the *Cornea* with the Launcet, and you see it run out upon the white Paper. — Pray, what do you think of it?

Euphros. Why, truly, it so much emulates *Water*, in Appearance, that I should not have known it had been any other Fluid, if I had not seen how, and from whence it came there: — But, upon letting it out, you have quite defaced the beautiful Appearance of the Eye; for now the *Cornea* loses its Convexity, and subsides in Wrinkles, which gives a ghastly Appearance to the Eye.

Cleon. I will soon relieve you from that disagreeable Sight. — With these anatomical Scissars, I sever the *Cornea* from the opaque Coat called the *Sclerotica*, and then you behold the next Part, which is destined for the Service of Vision: This, the Anatomists call the *Uvea*, (*K o L*) it is, in our Eyes, of a circular Form, and quite opaque, and, being of different Colours, it is vulgarly called the *Iris*. — In the middle Part thereof, you observe an oblong Perforation, which in human Eyes is perfectly round, and called the *Pupil*, (*o, o.*)

Euphros. The Instructions you have already given me in Optics, enables me to judge of the Use of this Part, at first Sight. The Pupil of the Eye answers to the Aperture in the object End of a Telescope, which must be of a determinate Size for a proper Degree of Light to illuminate the Image in the Bottom of the Eye. This Doctrine you frequently inculcated in your Description of optical Instruments, and particularly the *Camera Obscura*.

Cleon. What you say is true, in general, in artificial Optics: But when we consider the natural Structure of this Part, it will appear very admirable; for this natural Aperture,

Aperture, or Pupil in the Eye, is capable of various Dimensions, by a double System of muscular Fibres of which it is composed, *viz.* one of the external Part, which is of a *circular Form*, and by whose Action the Pupil of the Eye is contracted: The other System; on the interior Part, has its Fibres disposed like Rays issuing from the Center of the Pupil, and when I take it off, they will be very conspicuous.——You see I pass my Scissars round, and it is separated from the interior Coat of the Eye; and now the *radial* System of Fibres appear.

Euphros. I see them very plainly, and cannot but wonder at such divine Mechanism in this small and usually supposed inconsiderable Part of the Eye:——That when the Light of an Object is too glaring, we have the Faculty by one System of Muscles to contract the Pupil, and thereby to exclude all the offensive and superfluous Light: And on the other Hand, for distant and obscure Objects which require to be viewed with all the Light possible, we can, by the Action of the radial Fibres, dilate the Pupil, and thereby give Admission to a greater Quantity of Light.

Cleon. I have sometimes been curious enough to measure the Diameter of the Pupil in each Case: when a Candle has been held very near to the Eye of a Child, I have found the Pupil not much to exceed the $\frac{1}{3}$ of an Inch; but in the Twilight of the Day I have found the Diameter of the Pupil near twice as large, and therefore the Area of that Pupil near 4 times as great as before:——The *Uvea* being removed, you behold another Part, in a great Measure resembling a Lens of Glass placed just in the Middle of the Eye behind the Pupil.

Euphros. A very curious Part, indeed; pray, what do you call it;

Cleon. It is called, the crystalline Humour; for it is, as yet, contained in an exceeding fine transparent Capsule, called the *Arachnoides*, on the upper Surface of which you see a circular Zone of Fibres; these, also, are in form of Rays issuing from the Center, and are of a black Colour.

Euphros. They are very conspicuous ; I should be glad to know their Use, and by what Name they are called.

Cleon. This black *Annulus*, or Ring of muscular Fibres, is called, the *Ciliary Ligament*, as resembling the Hairs of the Eye-lids :——The Use of this Part, being affixed to the delicate Tunick of the crystalline Humour, is to give a proper Motion to the same, and as some think, to alter the Figure of this Humour in some small Degree, as will be farther evident when by making a fine Incision in the Capsule, the crystalline Humour immediately slips out, which I take on this printed Paper, that you may see how the Letters are magnified thro' it, as in a common Glass Lens.

Euphros. Amazingly fine indeed :——In my Life, I never beheld any Thing so transparent :——It seems, a perfect Glass Lens, but more polished than Glass, infinitely :——It may very well be called the *crystalline Humour*, I see, for no CRYSTAL can ever emulate this Part in regard to Clearness.——I observe one Thing very remarkable, and that is, though it be apparently, and (I suppose) really, of a spherical Surface on both Sides, yet, that one is considerably more convex than the other : Pray, what is the Meaning of this, *Cleonicus* ?

Cleon. As this Part is undoubtedly destined, by Nature, to correct and adjust the common Refraction of Light, through the Eye, to a proper Focus on the *Retina* at the Bottom, the convex Surfaces may, in some Degree, contribute thereto, as the Density of the crystalline Humour is a small Matter greater than that of the other Humours, in which it is contained ; and, by the Action of the *Ciliary Ligament*, the Degree of Convexity in each Surface may possibly be a very small Matter altered ; but Reason, more than Experience, directs us in these Conjectures.——However, it must necessarily follow, from the Nature of a muscular Ligament, that, by its Contradiction and Relaxation, the Position of the crystalline Humour must be subject to Alteration, and this is necessary in the Nature of Vision ; for, when Objects are near to us, their focal Distance becomes greater than when they are placed afar off, and therefore the Fibres of this
Ligament,

Ligament, by contracting, removes the crystalline Humour a small Matter farther from the *Retina*, and thereby procures a due focal Distance for nigh Objects: But, by their Relaxation, this Humour sinks lower, and shortens the focal Distance for those that are farther off; and thus the Eye is provided with a Power of procuring Vision for Objects in all Variety of Distances.

Euphras. There is no End to the Admiration of the Wisdom we observe in the Works of Nature, and the most evident Marks of Design and Contrivance in every particular Part.—But what is that large Quantity of Humour that fills the whole Body of the Eye, in Appearance like the White of an Egg?

Cleon. It is commonly called the *Vitreous*, or *Glassy-humour*: But for what Reason I know not, unless for that one Quality of Glass, its *Transparency*.——It is in a very large Quantity, in Respect of the other two Humours, on purpose to fill out the Body of the Eye, and to render it globous and roomy:—For, before I take this Humour out of the Eye, it is worth your while to observe how very perspicuously it shews the optic Nerve expanded over all the interior Part of the Eye, together with the Arteries and Veins which enter with it, and are most delicately ramified through all its Texture:——For the Blood Vessels ever accompany the Nerves through every Part of the Body; they circulate the Fluid of *Life*, as the other does that of *Sensation*.

Euphras. A Phænomenon equally curious and wonderful: It is impossible a finer Sight should greet the Eye. I see the whole Expansion of that noble Organ in its natural Position, the Idea of which will ever be indelible in my Mind!

Cleon. I shall shew you the same Thing, by-and-by, in a different View. That curious visual Membrane is every where connected with the fore Part of the Eye, immediately under the Ciliary Ligament, as you will easily perceive when I turn the Eye inside out, upon the Surface of the Water in this Glass, which supports the descending Humour, and the *Retina*, till, with the Knife, I have separated them both from the anterior Part of the inner Membrane of the Eye, called the *Choroides*, which

lies immediately under the *Retina*, and is beautifully coloured in *Quadrupedes*.

Euphros. I see the Separation manifestly :—— as your Knife proceeds, the glassy Humour subsides and becomes invisible in the Water ; but the optic Nerve remains behind, upon that fine coloured Coat you mentioned.

Cleon. Though the glassy Humour is not seen in the Water, I shall take it out upon a Wire,——and you see how very large and transparent a Substance it is.

Euphros. Pray, of what does this Humour consist ? there seems to be a great Quantity of aqueous Matter, as I see it continually keeps dripping a clear limpid Fluid like Water ?

Cleon. It from thence appears to be composed of a System of infinitely fine Vessels, which contain and continually distill the fine Lymph you see ; and so inconceivably fine are those Vessels, that, when they have discharged all their aqueous Contents, they scarcely amount to the Weight of a single Grain.——But now observe, I pass my Knife round the extreme Part of the *Choroides*, and the *Retina*, being by that Means separated, subsides into, and floats upon the Water, 'till at Length, the whole being fevered, it totally sinks and collapses into a Body almost in Appearance like the external Nerve.——I now cut away all the Coat of the Eye from the Nerve, and then it appears most evidently, that the *Retina* is only a Continuation of the Nerve.——Lastly, with my Scissars I separate the *Retina* at the Nerve, and let it fall into a Glass of clean Water ; then, with the Point of the Wire, I expand it, and you see how fine an Appearance it makes.

Euphros. It is, indeed, beyond all Expression, fine :——it resembles now a Piece of fine white Linen, of a curious Texture, and interwoven with a great Variety of Blood-vessels, in a beautiful Ramification, gradually eluding the Sight by infinite Degrees of Miniature :——But I observe this wonderful Part, this Organ, or Seat of the visive Faculty, is, in itself, not transparent, but almost opaké.

Cleon. Opacity, or Transparency, or both indifferent to the Cause of Vision, which consists wholly in the peculiar

peculiar Action and Modification of the Rays of the Light on the Filaments of the optic Nerve:—But its being in so great Degree Opaque, shews how far some Men may be carried from the most evident and obvious Truths, to support a new Hypothesis which has no Foundation either in Nature or Reason; but Truth will ever confront and prevail over Error, though supported with all the Powers of Rhetoric and Novelty. The optic Nerve, which immediately receives the Rays of Light, and sustains their first and whole Impulse, will ever be acknowledged the natural Organ of Vision by every modest and judicious Philosopher; and the *Choroides* must in vain pretend to rival it in that Honour, to which the Rays of Light can have no Admittance thro' the *opacus* Substance of the *Retina*, and must be content with the more humble Office assigned to it by Nature.——Thus much for the Description of the *Natural Eye*. At our next Interview I shall entertain you with an Account of the Deficiencies in the Structure of the Eye, and how they are rectified by the Application of Glasses, and illustrate the whole by an *artificial Eye*.

DIALOGUE V.

Of the preternatural CONFORMATION of the EYE; the DEFECTS of VISION arising from thence; and the Means of remedying them by OPTIC GLASSES. The whole illustrated by an ARTIFICIAL EYE.

Clemicus.

I Took an Opportunity, very lately, to let you see how accurately every Part in the natural Eye is contrived to answer the Purposes of Vision; that no Part could be wanting without a Deficiency in the Structure and Uses of that most noble of all Organs: On the other Hand, it appears that no Part was redundant, or superfluous: And again, with respect to the Position

and Figure of each Part, that it was altogether such as the Nature of Vision required: Upon the whole, the Eye is naturally of so just a Conformation that it stands in no Need of the Assistance of the Science of Optics, but in Regard to Telescopes and Microscopes, concerning which I have very largely discoursed to you heretofore.

Euphros. But how, *Cleonicus*, shall we then understand the Reason of so many defective Eyes, which we daily observe in all Ranks and Degrees of People, from the youngest to the oldest; for nothing is more common to observe, than that both Old and Young apply Glasses, concave or convex, to their Eyes, to mend their natural Sight?

Cleon. Your Animadversion is founded on a general Experience, I allow; but it must be considered, that all those who use the convex Sort of Glasses do it in the Course of Nature; for the Eye, like all other Members of the Body, is subject to Decay, and in our declining Years requires Assistance equal with every other Part, and consequently, this can be reckoned no preternatural Affection of the Eye: But with regard to young People, if they are obliged to use Glasses, it is from a real preternatural Conformation of the Eye; in them, the Eye is of a Figure too convex for making a perfect Image of Objects on the *Retina* in the Bottom of the Eye: but if we consider how very few there are of this Class, compared with the Bulk of Mankind, we must reckon them only particular Exceptions to Nature's perfect and handy Work.

Euphros. I have also heard of another Reason for the Use of concave Glasses, *viz.* that because some People in higher Life have been obliged, from a natural Necessity, to use them, others in lower Spheres (whose corporeal Eyes stood in much less Need of mending than those of their Mind) thought it became them to imitate their Superiors in this Respect; and so the Application of Concaves became improved into a Fashion.

Cleon. People are not only excessively fond of being in the Fashion, in setting off the real Beauties and Excellencies of their Persons with all the Extravagance imaginable,

imaginable, in regard to dressing, painting, &c. but they are so preposterous, as even to blemish and eclipse their natural Perfections to gratify this absurd Passion; witness, in your Sex, the *Patches* (which at first were only designed to hide Pimples), and in our's, the affected Practice of *Myopism*, or the Application of Concaves where none are wanting, and where they must do harm.

Euphros. Why is such a Person who uses a concave called a *Myops*?

Cleon. The Word *Myops* is of *Greek* Etymology, and signifies, in plain *English*, *Mouse-eyed*; because a Mouse has a very round Eye, or the Whole of it is almost a Spherule, or small Globe, as you may easily satisfy yourself when you see that Animal in a Trap; or, which is nearly the same Thing, you see such an Eye every Day in the beautiful little Squirrel you keep.

Euphros. You have satisfied me in that Particular.—By the Instructions you have heretofore given me, I believe, I am able to see the Nature of this Deficiency in the Eye, which you call *Myopism*, for it is, if I mistake not, an Eye with too short a focal Distance, occasioned by too great a Degree of Convexity in the *Cornea*, or anterior Part of the Eye.

Cleon. That is the very Case, my *Euphrosyne*; and that you may the better see and compare an Eye of a just Conformation with the two Sorts that are not so, I have provided three Diagrams, to shew their different Structures respectively. In one of these (Fig. 3. Plate LI.) an Object O B is placed at a proper reading Distance before the Eye, whose *Cornea* K P L, the Pupil o o, and crystalline Humour S T, with every other Part, are of a just Conformation to make the Image I M perfect on the optic Nerve at the Bottom of the Eye.

Euphros. This is all very evident in the Figure, where the focal Distance of the Eye is just equal to its Diameter:—But what is the proper reading Distance C P, at which the Object O B is to be held for viewing it in the best Manner?

Cleon. When we want to read, or view a Thing in the most perfect Manner, Nature, without our Attention, stretches out the Hand to about 14 or 16 Inches, according to the Difference of Eyes, which is seldom more

or

or less; and therefore, by Experience, that is confirmed to be the Distance for viewing Objects with the natural Eye.—But if the *Cornea* happens not to have this natural Degree of Convexity, as in the other Diagram (Fig. 4.) which you here see, where *K P L*, the *Cornea*, has a greater Degree of Convexity than what is just, the Rays which come from any Point *C*, in an Object at the Distance *C P* as before, will here be united, and represent that Point *C*, short of the *Retina*; and so all other Points in the Object *O B*, and consequently the Image thereof, will be formed and represented at *I M*, some Distance from the Bottom of the Eye.—As this is the Case, we find a near-sighted Person obliged to hold the Object much nearer to the Eye, viz. at *O B*, in order to lengthen the focal Distance, and make the Rays reach the Bottom of the Eye before they unite; and as they, in that Case, represent the Image perfect on the *Retina*, at *i m*, they procure distinct Vision of the Object in that near Distance *c P*.

Euphros. As the *Myops* has it in his Power to rectify this natural Defect of Vision for any Objects near him, or such as he holds in his Hand, by lessening the Distance between the Object and the Eye, till the focal Distance is thereby adjusted upon the *Retina*: So a concave Glass cannot be necessary on that Account — It must therefore be only for viewing remote Objects, where the Distance is unalterable, at least cannot be diminished so much as is necessary for a just Prolongation of the Focus of the Eye, and where, of course, a concave Glass must be applied to perform that Office.

Cleon. You seem to have very just Ideas of this Matter; for the concave Glass *E F* being applied before the Eye, diverges every Pencil of Rays *a C b* in such Manner, as to make them fall upon the Pupil *o o*, as if they came from the Point *c* at a much less Distance from the Glass *E F*; and when the Concavity of this Glass is such as the near-sighted Eye requires, then will the Image *i m* be duly formed on the *Retina*, of the distant Object *O B*.

Euphros. This I apprehend very clearly, and, with Regard to a *Myops*, I observe, that any Object *O B* appears less to him, as *O B*, and also at much nearer Distance

Distance than to a well formed Eye.——Hence likewise it must follow, that as there may be various Degrees of Convexity in the Eye beyond that which is just, so there must be a great Variety of concave Glasses necessarily corresponding thereto, and to be used as Remedies for the same.

Cleon. After the same Manner you will understand, by the third Diagram, (Fig. 5.) for that *Presbytæ* (which is a Greek Word for *elderly People*) the Cornea K P L has too small a Degree of Convexity to converge a Pencil of Rays *a C b* coming from a Point C (in any Object O B at the natural reading Distance (as in Fig. 3) to its proper focal Distance at the Bottom of the Eye; but they will proceed to a Point beyond the Eye, where, if they were not intercepted, they would form the Image (*i m*). Now though such a long-sighted Person might remove a Book, or other Object, to such a Distance from the Eye, that he shall be able, by that Means, to shorten the focal Distance of the Rays, and read without a Glass, yet this would be attended with great Inconvenience, in general, and the reading at so great a Distance would be awkward and unsightly, as well as unnatural: Therefore, by applying the convex Glass G H, the aforesaid Pencil of Rays (*a C b*) is made to fall less diverging upon the Eye, or as if they came from the Object O B at a greater Distance. By this Means, that Pencil of Rays is duly converged to a Focus at the Bottom of the Eye, and thus all other Points in the Object O B will be represented in the Image I M on the *Retina*, and thereby produce distinct Vision.

Euphros. All this too I cannot but apprehend, as you have partly explained it to me in a former Conference:—And also, from the Figure, it is easy to infer, that, to a *Presbyta*, Objects appear through Glasses magnified, and at greater Distance, just the Reverse to the Case of the *Myops*.——You have now led me through the *Rationale* of those we call ocular Glasses, both concave and convex, that are used for rectifying Vision in general. Have you any Thing farther to observe, with respect to the Manner of applying them to the Eye with the greatest Advantage?

Cleon

Cleon. Yes; there are two Things which, by the Laws of Optics, every rational Man must think himself obliged to observe and conform to: The first is, that no more Light be admitted upon the Eye than what is necessary to illuminate the Object, shew it distinctly, and to allow of a sufficient Field of View: But, on this, I have already expatiated to you, which needs no farther Repetition*.

Euphros. I remember very well what you said to me on that Subject, and am thoroughly convinced of the Reason of it: But what is the second Particular to be observed in the Use of these Glasses?

Cleon. The second Thing necessary in the Application of these Glasses is, that they are so placed before the Eye, that the Axis of each Glass may coincide with the Axis of the Eye, and be therefore directed to, and united in the Object that we view: This must be observed very strictly, with regard to Convex Glasses, as by them we view near Objects; but it has little to do with Concaves, as the Objects seen by them are generally remote, and therefore the Error, in this Respect, almost insensible: But as this Matter cannot well be explained, without a large Copper-plate, I must refer you to a Treatise lately published on this Subject, where you will find ample Information concerning this, and all other useful Precautions in the Use of VISUAL GLASSES, and their Difference from the absurd and injurious Structure of common Spectacles.†

Euphros. But after all, you promised to illustrate this Affair by an *artificial EYE*, which I take to be this round Globe of Brass on a Pedestal, with a Glass before and behind. Pray, what is the Structure and Similarity between this and the natural Eye?

Cleon. If great Art and Expence were employed, there might be a very considerable Likeness produced between the Structure of the natural and artificial Eye, so far that in every Part they should each of them have nearly the same Appearance:——But without regard to the Size and

* See Dialogue XVII, p. 317, 318.

† See the *Appendix* to my *Philosophia Britannica*, 3d Edition,

and Form of the constituent Parts, a great Similarity may be produced in the Effects of one and the other; and this is sufficient for our Purpose, as, by Means of this artificial Eye, in a very simple Structure, we can easily represent or illustrate the three different Cases of natural Eyes before mentioned; and for this Purpose only four Glasses are necessary, three of which are Convex ones, and finely polished, included severally in proper Cells or Rims, and to be screwed into the same Hole on the Fore-part of the artificial Eye. The Fourth is a plain Glass, ground on one Side with fine Emery to take off the Polish, and thereby to render it, as it were, Semi-transparent.

Euphros. By your very Description of this last Glass, I suppose it must represent the *Retina* in the natural Eye, which, I remember, you shewed me was neither Opaque nor Transparent, but between both.

Cleon. I observed to you, at the same Time, that this Quality, or Degree of Transparency in the *Retina*, did not appear to be necessary to Vision; but in the artificial Eye it really is so, because, were this Glass wholly Opaque, or Transparent, it could not answer the Purpose; as in one Case, no Image of an Object could be seen upon it; and in the other, though the Image might perfectly appear, yet its Locality, or particular Place, could not be so well determined: But being thus half transparent, will nicely shew the *Image*, and the *Place* where it is formed at the same Time.

Euphros. I understand you perfectly well; but I observe this Glass is plain, and has not the true Figure of the hinder Part of the Eye.

Cleon. That Figure would not be easily imitated by Art, as it is neither plain nor spherical; Nature takes a perfect Method in all her Operations: Art can only imitate by Approximation, but a plain Glass will answer our present and particular Design.

Euphros. The three Glasses which are screwed on in the Fore-part of this Brass Eye are, I presume, designed to form the Images of Objects on this artificial *Retina*, or Glass, behind; and, because you have three in Number, I suppose one is to represent the Case of a well-formed Eye, and the other two the deficient Ones of the *Myops* and *Presbyta*?

Cleon. That is the very Thing, my *Euphrosyne*, as I will now shew you by an Experiment.——The Diameter of the artificial Eye, you observe, is two Inches:——Then I screw on the Glass (N^o 1.) whose focal Distance is just 2 Inches:——Then I take the artificial Eye, and standing at the Distance of about 12 or 15 Feet from the Window, and holding the artificial Eye directly before my own Eye, I see the Image of the Window very distinctly formed upon the ground Glass.——Now, take the Eye in your own Hand, and standing at the same Distance, you will observe the same Thing.

Euphros. That I do perfectly; and a very curious Experiment it is:——The Window appears in all respects like the Picture of Objects in a *Camera Obscura*, most natural, bright, vivid, and every Way the same, I presume, as it would appear on the *Retina* of the Natural Eye, if it was possible to be there seen.

Cleon. See it you may in the natural Eye, in some Measure; and, as I know you are very curious in these Matters, I have prepared such an Eye on Purpose to shew you this very Phænomenon therein.——You here see the large Eye of an Ox divested of all its muscular and membranous Parts, and then a circular Hole cut in the *Sclerotica*, or external Coat of the Eye, and also through the *Choroides* which lie immediately within it, and then a Part of the *Retina* appears entire and in its natural State:——Then I hold this natural Eye up against the Window, and you see the Image of the Window perfectly formed on the *Retina*, just in the same Manner as in the artificial Eye.

Euphros. This is, indeed, an *experimentum Crucis*, or capital Experiment in Vision, than which nothing can give a more full and exquisite Satisfaction, with regard to the Manner how Vision is performed in the Eye.

Cleon. But now if a Glass, either convex or concave, be placed before the *Cornea* of the natural or artificial Eye, the Image no longer appears distinct on the natural or artificial *Retina*, as you may try with each Eye severally, while I apply each Sort of Glass before them.

Euphros.

Euphros. Then I will take one of the Eyes in one Hand, and the other in the other, and, if you please, first apply the Convex:——In each Eye the Image disappears, at least its Appearance is very confused.——Now apply the Concave, that I may see the Effect of that:——It is very much the same as before, no Beauty or Distinctness of the Image any longer appears, and consequently no Perfection of Vision in the natural Eye.——Hence it appears, however useful those Glasses may be on some Occasions, yet, when the Eye has its due Form or Figure, they can never be used without prejudicing the Sight.——Please now to shew me the Experiment of the *Myops*.

Cleon. For this Purpose I must screw on the Glass (N^o 2.) whose focal Distance is only one Inch and a Half, arising from its greater Degree of Convexity. In this Respect it will represent the *Cornea* of a short-sighted Eye, as well as in its Effect of forming the Image short of the *Retina*, and, consequently, it must appear very imperfect upon the Glass behind:——hold it up against the Window, and see the Consequence of such a convex Glass.

Euphros. I do:——It very plainly appears, that no Image of the Window, or any other Object at a Distance, can have its Image formed in any Degree of Distinctness on the glassy *Retina* of this Eye.——Now, please to put before it the concave Glass, for a Remedy.

Cleon. I will:——It is now just before the artificial *Cornea*, and, by causing the Rays to go less converging, they proceed to the ground Glass before they unite in a Focus, and there make the Image as perfect as before.

Euphros. I very plainly perceive it; but I observe at the same Time, that the Image of the Window is not so large as before, which gives the Reason why short-sighted People see all Objects of less apparent Magnitude than other People do, a Thing I remember you formerly observed to me.——You will next favour me with an Experiment of a long-sighted Eye, which requires a Convex Glass.

Cleon. In order to this, I shall put on the Glass (N^o 3) where the focal Distance is two Inches and an Half,

Half, which, as it exceeds the Diameter of the Eye, the Image will necessarily be seen very imperfect on the Glass behind:——But when I apply a Convex Glass between the Eye and the Window, you will then see, by this additional Convexity, that the Rays will be made to converge to a Focus on the glassy *Retina*, and there represent the Image of the Window perfect.——Take it in your Hand, and try the Experiment.

Euphros. I will first hold up the Eye without your Visual Glass:——There is not the least Appearance of any distinct Image: One may just see it is a Window, and that is all.——Please to apply the Convex.——I now see the Image of the Window restored to its perfect Form, but much larger than in either of the foregoing Cases:——By this Experiment I am also satisfied of the Reason why those who use Visual Glasses must necessarily see all Objects larger than they appear to the naked Eye well formed: And since this is the Case, how does it come to pass, *Cleonicus*, that we do not hear short-sighted People speak of seeing Things smaller, or old People of seeing them larger, than others who use no Glasses at all?

Cleon. There is no such Thing in Nature as a Standard of real Magnitude, but only of that which is apparent; an Inch, or Foot, or Yard, is as much a Standard Measure to a *Myops* or *Presbyta*, as to a Person who views it without a Glass: And since to each Person every Thing appears diminished or magnified in the same Proportion, they must necessarily all of them have the same Ideas of apparent Magnitude, as the Scale of Comparison is still the same in all; for Things are only great or small, by Comparison made in the same Scale, or by the same Standard.——There is only one Thing now which remains to be confirmed by an Experiment, and that is, to shew how much more distinct the Image of any given Object is formed by a Glass of a proper Aperture, than by another of an exorbitant Size: For Instance, that which you have seen in the Eye of two Inches Focus is only $\frac{3}{4}$ of an Inch in Diameter: I will now put on another Glass which is twice as much, or one Inch and an Half in Diameter; it is of the same focal

focal Distance, and will form the Image of the Object on the Glass as before, but with four Times the Quantity of Light; on which Account, the Distinctness of the Image will be greatly impaired, and, consequently, the Perfection of Vision which depends upon it, as you will observe by the Experiment, is destroyed.

Euphras. This is a very plain Case:—The Image is now quite suffused, or overwhelmed, as it were, with Light; and far from being so distinct and perfect as it was before: By which I am thoroughly convinced what Judgment and Care is necessary for giving such Apertures to optical Instruments as are necessary for their due Perfection, and, particularly, how absurd it must be to covet a large Spectacle-glass, when one of a smaller Size will so much better assist the Sight.—But I suppose, by this time I have sufficiently tired you with such a tedious Series of Speculations in Optics:—It will be a Relief and Pleasure to you, as well as me, to change the Subject, and make a Transition to some other Object of natural Science, that may afford another kind of Entertainment. What can you think of, *Cleonicus*, that will offer itself most proper for that Purpose?

Cleon. Why truly, my *Euphrosyne*, we have dwelt long on the Science of Optics, and yet have not exhausted the Subject; but, as my Design is to give not a critical, but cursory View of general Topics, I shall now direct your Thoughts to another important Branch of Knowledge, which is the *Doctrine of Sounds*, and give you an Idea, so far as I am able, of the wonderful Mechanism and Structure of the EAR, which is that Organ that renders them perceptible to the Mind, and which, I presume, you will find a Subject not much inferior, in Point of Curiosity and mental Improvement, to that of the Organ of Sight.

DIALOGUE VI.

On the general NATURE and CAUSE of SOUNDS.

Cleonicus.

FROM the Science of OPTICS we now proceed to that which is called ACOUSTICS, which treats of the Philosophy, or Doctrine of SOUNDS, and of the Constitution of the Organ of HEARING, placed in the EAR, by which those Sounds are rendered audible, or sensible to us, under all their different Affections and Circumstances.

Euphros. This Subject must necessarily afford me very useful, very instructive and entertaining Lessons; for, as the Subject is that of Sound, I naturally conclude, that the Science of Music will make a considerable Part of our Speculations, as it consists wholly of an artful Modulation and Modification of different Kinds of Notes, or Sounds.

Cleon. Music is undoubtedly the essential and most refined Part of the Philosophy of Sounds; an agreeable Scene in Optics, or Perspective, does not more delight the Eye and regale the Mind, than a Composition of harmonious Sounds delights and pleases the Organ of Hearing, and, perhaps, of all our Sensations: This does more immediately affect both the *pathetic* and *rational* Part of the human System; and hence it is, we see Mankind in general so fond of musical Sounds, as it affects them with the most agreeable and ravishing Sensations: But what inclines me most, at present, to discourse to you on this Subject is, the exquisite Taste and Relish you have for the Pleasure of this Science in every Respect, and consequently a *Rationale* of those Instruments, with which you so frequently delight yourself and Acquaintance, will be very grateful to you.

Euphros. Nothing can prove more so; and I remember you formerly hinted to me, when you treated of Air in general, and shewed the Experiments on the Air-pump, that the Nature of Sounds depended entirely upon a certain Motion of the Particles of Air, and that by one particular Experiment of the Bell it was shewn, that

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when the Air was exhausted, or taken away, no Sound from the Bell could be heard. It is this Motion of Air therefore, I presume, and its various Effects, that you now propose a farther Explanation of.

Cleon. This is more immediately the Object of our present Disquisition: But as I have formerly told you, there is a two-fold Motion in the Air, which ought to be separately considered, to have a distinct Notion of either; the first regards a Motion of the whole Body of the Atmosphere, or any Part thereof from one Place to another; but the second respects the Motion of the Particles of Air in themselves simply considered, and is not so much a *local Motion*, from one Place to another, as a pulsive or vibrating Motion, which carries the Particles forward and backward, through the very same Space. Do you think you apprehend me in this Distinction, my *Euphrosyne*?

Euphros. I believe I do, *Cleonicus*.—By the first Motion of the Air, I conceive a great Quantity of it is carried from one Part of the Globe to another, after the Manner we usually call *WIND*, as you formerly explained to me, when you treated of the general Nature of the Air and Winds.—But the second Motion of the Air, or that rather which respects the Motion of the Particles of Air in themselves considered, I cannot say I have so clear an Idea of; but apprehend it must result from, or depend upon that Power which you convinced me existed between the Particles of Air, which keeps them all at an equal Distance from each other, and is that which you called the *Spring*, or *Elasticity* of the Air.

Cleon. You recollect very well, my *Euphrosyne*; it is by Means of this Power that, when any one Particle is by any Cause urged forward, it must necessarily propel the Particle next before it; this second Particle, in the same Manner, moves the third; and the third, the fourth; and so successively: By this Means a Motion is produced, and propagated in the several Particles of Air, through a certain Space in a Direction forward; but then, on the other Hand, when the Force which was first impress'd upon the elastic Particle of Air is remitted, or ceases to act, the Particles return again, by the Action of this elastic Force, through the same Space. And,

lastly, if this Force be repeated, at stated Intervals, on these elastic Particles, there must necessarily be produced in them a mutual vibratory Motion of each Particle, so long as the repercussive Force continues to act: And it is this Motion of the Particles of Air that is the Cause of Sound in general.

Euphros. Indeed, *Cleonicus*, this is such a nice Speculation that, without a more circumstantial and plenary Explanation, I fear I shall scarcely be able to get such clear and adequate Ideas, as I could wish, of the Nature of Sound: But, I suppose you can render it more facile by Experiments, or some Illustrations of that Kind?

Cleon. I can assure you, my *Euphrosyne*, there is no one Part of natural Philosophy more intricate and difficult to explain than the Nature and Action of an elastic Fluid. This was experienced and acknowledged by Sir *Isaac Newton* himself; and we find, by his Commentators on his *Principia*, that it was in treating of this Subject only, that they apprehended this great Man capable of a Mistake: But it will not follow from hence, that, because some Parts are exceeding difficult, we should not contemplate and improve our Minds with the Study of those which are more easy and useful; and therefore, to facilitate your Apprehension of what relates to the Doctrine of Sounds, I shall consider in the first Place, the Nature of those Forces, and the Manner in which they act on the elastic Medium of Air, by which that peculiar Motion is generated which proves the Cause of Sound.——Secondly, the general Properties of the Pulses of Air, and the Manner in which they are propagated.——Thirdly, the artificial Modulation of Sounds, both instrumental and vocal, so as to render them harmonious and musical to the Ear.——Fourthly, the Organs furnished by Nature for forming and variously modulating animal Notes, or Voice.——Fifthly, the particular Construction of the Organ of Hearing, placed in the Cavity of the Ear, for raising in the Mind the Sensation of Sound.

Euphros. These seem to be very curious and important Topics, and it will give me great Pleasure to hear you explain and expatiate upon them: Please, therefore, to begin with the first of them, in which you signify the original Cause of Sound consists.

Cleon.

Cleon. The first Thing to be considered in the general Idea of Sound is, the percussive Force, or Stroke, which is made upon the sonorous Body, whose Parts are thereby put into Motion, and this Motion is to be understood to be that which is produced by elastic Parts, or Particles, of which such Bodies consist; for without such an elastic Disposition of Parts they could not by any Means be rendered sonorous, or capable of emitting Sounds, because the Stroke, being made externally, affects the Particles of such a Body but with one single Act; the Particles of the Body could therefore, in such a Case, be moved through a certain small Space, and would there stop by the Resistance of the Parts beyond; and without an elastic Force the Particles would remain at rest, after the percutient Body is removed; and therefore, from one single Stroke, the Parts of Bodies unelastic could emit but one single Sound, as they can affect the Air but by one single and unrepeatd Action: In such Cases we usually say, *we hear the Stroke*, and that is all, as when we strike with a Hammer on a Piece of Lead, and other soft and unsounding Substances:——But when we consider the Stroke impressed on Bodies, whose Parts are in any considerable Degree elastic, they not only yield to the Stroke and go forward through a small Space, but, after the striking Body is removed, those elastic Parts, by their renitent Force, return again with a Velocity equal to that by which they were displaced: And thus a Motion being produced of a vibratory Nature will continue a sensible Time, and produce successive Impulses on the contiguous Air; and the Air being thus agitated by the elastic Particles of the Body, transmits its Pulses successively to the Ear, and there produces a Sensation of Sound of some Duration: And these are what we properly call sonorous, or sounding Bodies.——Thus, a fine wire String being strained with a Weight, or otherwise, becomes elastic, and if it be properly struck with a Quill, it will emit a Note, or Sound, which will continue audible a considerable Time after the Stroke.——Also, if a Bell, or Glass, be struck in a proper Manner, they will emit Sounds of considerable Duration; for which Reason they become the fittest Instruments for musical Modulations.

Euphros. These Things I am well assured of from every Day's Experience; but there is one Thing I observe in the Account you have given, which seems to render the Word *Sound* of a complex Signification, or as if it was one general Idea composed of an infinite Number of simple Sounds, so quick repeated as to be all united in one: For, by what you say, I collect that at each Return of the vibrating Particles of the Body, a new Motion is impressed upon the elastic Particles of Air, and, consequently, that the Pulses of Air will succeed each other at Intervals of Time equal to those in which the vibrating Motion of the Parts of such Bodies are performed; But as those Intervals, or Moments of Time are so exceeding short, as to be altogether insensible, the distinct Succession of the Pulses of the Air must be so too, and consequently they altogether constitute but one general, or compound Sound. Is not this the Case, *Cleonicus*?

Cleon. It is, my *Euphrosyne*, and as accurately as I could have expressed it myself.—The Case here is much the same as in Optics: A Beam of Light, consisting of Rays infinitely different in Refrangibility, will cause that each particular Sort of Rays shall make one particular Image of an Object in the Axis of a Glass; and consequently, that though an Infinity of Images are thus formed, yet, being infinitely near each other, they all make but one compound, yet very distinct, Image to the Eye.—Or thus: You have seen an Experiment, no Doubt, of a Boy's whirling round a red-hot Coal, which, to Appearance, makes a very complete fiery Circle; but this is only a general Idea arising from the particular Ideas of the Coal in the several Parts of the Circle; and as the Coal succeeds to those Parts so very quick, that there is no Time for the first Idea to be obliterated before it is excited again; so the Idea of the Coal in every Part of the Circle remaining, they must necessarily exhibit to the Mind the general Idea of a Circle of Fire, as aforesaid.—And, indeed, if we rightly consider Things, we shall find that most of our Sensations are performed in the Gross; that our Powers and Faculties are not sufficiently acute and perfect to distinguish or comprehend the most minute and simple Operations

Operations of Nature.——It is the same in regard to all our other Senses: Our *Smell* consists of an infinite Number of particular Sensations raised by the Action of innumerable *Effluvia* on the Organ of that Sense: And the like may be said of the Sensation of *Taste*, from *saporific* Particles.

Euphros. As this is the Case, how comes it to pass that our Ideas of those very complicated Sensations should yet be so very distinct and perfect as they are?

Cleon. Your Question is very *apropos*, my *Euphrosyne*, and I must answer you in the Dialect of the Musicians, that the particular Sounds excited by the elastic Particles are all Unisons, or of the same Note, and therefore can make all together but one Sound to the Ear, or rather a Sound of but one Note ——An inconceivable Number of small Drops of Water put together form only one larger, or collective Drop, which, in every respect, resembles each one of the smallest:——So the Action of an infinite Number of Particles, being all of the same Tenor, excite only a general, or collective Idea of the same Action on the Organ of *Smell* or *Taste*: But this is an Affair which requires not so much Prolixity of Explanation to my *Euphrosyne*.

Euphros. Indeed, I think you have given me a very clear Account of the first Operation of Nature in the Production of Sound.——The second Thing you proposed, I make no doubt, will prove equally satisfactory, to the Explication of which I shall be equally attentive.

Cleon. The Properties of the Pulses of Air, in which the immediate Cause of Sound consists, I cannot better illustrate than by making, in some Degree, a Comparison betwixt them and the Waves of Water, as well in Things wherein they disagree as those wherein they agree, and they will mutually help to explain each other; the Principle of which are as follow:——If a Stone falls on the Surface of Water, by its Weight, or Force, it will strike and descend into it: But the Descent being sudden, or momentary, gives no Time for the Particles of Water to move Sideways to make room for the Stone, but are forced to rise instantly, as it were, upwards above the common Level; and being raised up, they descend

again, by Virtue of their Weight, just as far below the Surface: In doing which, they must drive a Part of the Water beyond them into a higher Situation, and so produce a second Wave: This, again, upon its Descent, causes a third Elevation, or Wave of the Water next beyond it: And this, in descending, a Fourth, and so on, till at Length they reach the Bank, or Shore, upon which they break and vanish.—And here it is very remarkable, that the Generation of Waves in Water being produced by the Power of Gravity, their Motion will be analogous to that of a Pendulum, which is produced by the same Cause.—The larger the Body is which descends in the Water, the larger and more rapid will be the Motion of the Waves; and it is found both from Reason and Experience, that if a Pendulum be of a Length just equal to the Width of the Wave, their Motions will both coincide, or be performed in the same Time.

Euphros. Now let me see, *Cleonicus*, before you go farther, if I can illustrate to myself this Matter by an Example. I have heard you say oftentimes, that if the Length of a Pendulum be $39\frac{1}{8}$ Inches, its Vibrations will be performed in a Second of Time; from whence I infer, that if a Stone falls upon the Water that shall produce Waves at the Distance of $39\frac{1}{8}$ Inches from each other, then they will move through that Space, or succeed each other in a Second of Time.

Cleon. You completely understand this Affair, I see: —Therefore I shall next observe that the Pulses of Air and Waves of Water disagree in their Cause, since the one is owing to Elasticity, and the other to Gravity; but this, notwithstanding, they both agree with the Pendulum in the Nature of their Motion, as they are all of the vibratory Kind.—Another Thing in which the aqueous Waves differ from aerial Pulses is, that the former are of a circular Form, as generated on the plain Surface of the Fluid; but the others are necessarily of a spherical Form, as they are produced in the Body of an elastic Fluid.

Euphros. This, on the Surface of the Water, is evident to Sense; the Waves are there concentric Circles: And in the Body of Air I find no Difficulty in apprehending

hending they must be of a spherical Form; for as the Motion begins from the founding Body, it must be communicated to, or equally impressed on all Parts, which therefore must generate Pulses of Air, diffusing themselves equally every where in a spherical Form.

Cleon. You are, indeed, very happy, my *Euphrosyne*, in your Genius for physical Speculations:—In Consequence of this Property of the Pulses of Water and Air, we may easily observe another, which respects the Degree of Strength in each Pulse, or Wave, as the Force of the first Wave is spent in generating the Second; and that second Wave being a Circle at a greater Distance than the First, will occasion a much greater Quantity of Water to be put into Motion, consequently, the Force in any particular Part of the second Wave will be as much less than it was in a like Part of the first Wave as the Quantity of Matter was greater, *i. e.* the Force in the second Wave is to that of the first Wave, as the Circumference of the First is to that of the Second; or the Forces decrease as the Waves increase in Circumference, or as their Distance from the Center is greater. — But with respect to the Waves, or Pulses of Air, the Case is different; for these being of a spherical Form, the Force in each must necessarily decrease in Proportion as the spherical Superficies, or the aerial Pulses increase, which, as the Geometers demonstrate, is in Proportion to the Square of the Distance from the Center.

Euphros. That is, if I understand you right, *Cleonicus*, the Force in the second Wave of Water is but half as great as the First, and the third Wave is 3 Times weaker, and so on; but in regard to the Pulses of Air, the Force of the Second will be 4 Times less than that in the First, and in the Third it will be 9 Times less; in the Fourth, 16 Times less, and so on. — But one would think, as the Pulses of Air decrease so fast, they could not have that very great Effect upon the Drum of the Ear, or produce so loud a Sound as they generally do.

Cleon. Our Organs are so constructed as to have the strongest Ideas excited by the smallest Action of natural Bodies upon them. How infinitely small are the Actions
of

of the Particles of Light on the optic Nerve in the Eye, and yet how great and glorious are the Ideas which thence arise ! In like Manner, we perceive how very sensible the smallest Motions of the Air will be, by a common Whisper, which is sufficiently audible to a good Ear ; or the most feeble Notes produced from a sounding String, as they die away.

Euphros. I frequently observe the Things you speak of with Wonder and Admiration.—And another Thing I observe will follow from what you have said of the spherical Pulses of Air, and that is, that the Sound of a Body must necessarily be heard on every Side, and be equally strong at an equal Distance.

Cleon. This naturally follows, from the Manner in which they are propagated, as you rightly observe ; and I shall farther add, that if the Waves on the Surface of Water are obstructed by any Obstacle, as suppose a large Plane with a Hole in any Part, the Motion of the Waves, as they apply to the Hole, will be propagated through it, and on the other Side will begin to spread themselves into a circular Form ; because the Motion, produced in any Part of a Fluid, is impressed every Way equally, and therefore from the Hole, the Agitation of the Water will proceed in a circular Form as well as from the Body itself which produced it.—It is in the same Manner that they are continued by the Sides of an Obstacle, and, after having passed beyond it, begin to diffuse themselves into circular Forms behind it. This you may easily try, by an Experiment even in a Vessel of Water.

Euphros. I shall amuse myself with Experiments of this Kind at my Leisure.—I suppose you conclude from hence, that the Pulses of Air too, after they proceed through Holes, and Obstacles round about their Surfaces, in like Manner diffuse themselves, and proceed every Way in a spherical Form.

Cleon. They certainly do so ; and from thence it is that we find, if a Gun be fired on one Side of a Hill, a Person placed any where on the other Side will be very sensible of it. But as the Waves of Air in this Case must take a much larger Circuit to reach the Ear, the Sound must, of Course, be weaker, than where there is no such

such Obstacle, and it arrives in its shortest Course and with its full Force.

Euphros. You have instanced some Particulars wherein there is a considerable Resemblance between the Effects of Optics and Acoustics, in the Formation of the Images of Objects, and Sounds in striking Bodies; but pray, *Cleonicus*, is there any Conformity in the Manner in which Light and Sound are propagated? The Reason of my asking is, that I have read and heard more on that Subject, than I was ever able to comprehend.

Cleon. That you may very easily do, my *Euphrosyne*: When People undertake to explain Things by an Hypothesis not founded on the plainest Dictates of Reason, and unsupported by the most indubitable Experiments, it is no Wonder if we hear them say a great deal which must be necessarily unintelligible to every Body. Such is the Case when we are told of a *subtle Medium*, by the Undulation of whose elastic Parts, the Particles of Light are put into a vibrating Motion (like the Particles of Air we have been speaking of), and therefore the various Sensations of Vision are occasioned by these *lucific Pulses* of the subtle Medium, in the same Manner as Sounds are produced by those of common Air.—— But if this was the Case, you will easily apprehend that all the other Properties of Motion, produced in an elastic fluid Medium, must necessarily be allowed: One of which is, that such a pulsive Motion of Light being excited, its Undulations will be continued every Way equally, and, consequently, in their Passage through Holes, and by the Sides of Obstacles, they will (like those of elastic Air) expand themselves into all the bordering Spaces round about, and even behind those Obstacles, and so, of Course, would fill all the Parts behind such Obstacle with Light: But this we find is contrary to all Experience; the Rays of Light, intercepted by any Sort of Obstacle, leaving the Spaces wholly dark behind, and those dark Spaces, or Shadows as we usually call them, are always such as are terminated by Right-lines drawn from the extreme Part of the radiant Object, and that which intercepts its Light.——The Motion of Light, therefore, is undoubtedly propagated in Right-line Directions only, from a pulsive

pulsive Force it originally receives in its proper Fountain the Sun, which renders the Doctrine of a subtile Medium unnatural and absurd, in respect to the Propagation of Light.

Euphros. I am thoroughly convinced, by what you have said, that Light cannot be propagated in the Manner Sounds are; for, if that were the Case, they would bend round the Sides of the Earth, and make us one perpetual Day:—An Eclipse of the Moon would be a Thing impossible in Nature, and we should never have known or have had the least Ideas of a Firmament of useful Stars ——— It appears to me, that the plainest Things in Life may be perverted into a Matter of surprising Disputation, by a Set of People who seem to have no intellectual Optics, since even the very Doctrine of Shadows itself must, one would think have beamed on their Minds the Light of Truth.—But to return: Pray, what are the next remarkable Properties of Air in respect to Sounds?

Cleon. The next Property of these aerial Pulses is, that they are subject to a Reflection from any fixed Plane, or Obstacle, from the same Cause with that of the Particles of Light; for the Particles both of Light and Air, being solid Bodies, will be equally reflected by the Reaction of the Particles of any fixed Object on which they strike; and this Reflection of the aerial Particles must necessarily produce Agitations, or Vibrations in the Medium, which proceed every Way equally in Form of spherical Shells, as before, and this repercussive Motion of the sonorous Air will produce a second Sound, or rather an Image of the First, if one may so speak; and this Repetition of the Sound is what you have been so often amused with under the Name of an ECHO.

Euphros. In all this I understand you very well, as there is no more Difficulty in conceiving the Relation there is between the Sound and its Echo, than there is between the Object and its Image by reflected Light: ——— But a Circumstance in which they differ is this, that, with regard to Light, the Angle of Reflection, to the Eye, must be equal to that of Incidence, that the Image may appear: But, let me stand where I will, I hear the Echo, though not equally plain and distinct.

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— I have often taken Notice, when I have been walking in the Fields, at a Distance from the Town, that this Reflection of Sound has been extremely sensible in a Variety of Echos, from every considerable Sound which has had Force enough to strike against the Side of our Church, for producing such a Repercussion or Reflection: Thus, the Report of a Gun is always heard twice; and it was not long since I observed a Man cleaving of Wood at about a Quarter of a Mile Distance from the Church, and every Stroke upon the Wedge was resounded, or echoed from the Side of the Church in so distinct a Manner as afforded me no small Amusement during the Time of Observation: But one Thing I took particular Notice of, which was, that the Echo did not succeed immediately to the Sound of the Stroke, but after an Interval of Time so considerable, that I could not help taking particular Notice of, and reflecting some Time on the Cause, or Reason thereof, which, at Length, I concluded must be, the temporary and progressive Motion of Sound: By which Means, the Time which the Particles of Air employ in this direct progressive Motion of their Vibrations from the Man to the Church, and from thence to the Ear, is such as makes the Echo at such a sensible Distance of Time from the Sound itself.

Glean. These Echos oftentimes afford a pleasant Amusement to the Curious, especially where and when you find such Surfaces which are called the *phonocamptic Plane*, that shall reflect the Particles of Air with the greatest Regularity and Perfection: For, in the Writings of Naturalists, you will oftentimes find such Histories of Echos as are very surprising, and almost incredible; such, for Instance, as will repeat not only Syllables, but even Words, distinctly, and sometimes so many of them as really to make the Echo speak; from whence these Echos are called *polyphonous*, *tautological*, or prattling Echos, which oftentimes afford a pleasant and ludicrous Theme as well to the Poet as the Philosopher, as you may see in *Bishe's Art of Poetry*, and other Compositions of that Kind, under the Word *Echo*.

Euphros. Then, I suppose, this very Phenomenon of a talkative Echo will have another Instance of Resemblance

blance to that of reflected Light, *viz.* that whereas the Image is seen in the Direction of the reflected Ray, and consequently in or behind the Glass, just so, I imagine, the Voice of the Man who is speaking must, in the Echo, be heard as coming from the Plane; and therefore the Man himself and his mimic Echo must be heard from two distant Places; for thus it is, I know, by Experience, in all the single Echos I have heard.

Cleon. In this you are perfectly right: And, to carry the Comparison still farther in regard to the Reflection of Light and Air, it is to be observed, that as the Image by Reflection from a plain Surface is nearly as strong, vivid, and perfect as the Object seen by direct Rays, so, in the Repetition of Sound, the Echo differs but very little from the original Sound, unless the Distance be great; and still nearer would it approach thereto if the phonocamptic, or reflecting Plane for Sound, was polished as perfectly as that for the Reflection of Light. And I can assure you, my *Euphrosyne*, were I possessed of that enormous Wealth as many Persons are, I would make it my Business to find the best Situation of a Plane for reverberating Sounds, and then would directly face the whole with Stone or Marble of a curious polished Surface, on Purpose that it might be found, by Experience, what perfection this Part of *Acoustics*, which relates to Echos, is capable of.——Again; as a polished Plane neither magnifies nor diminishes an Object, so neither can it increase or diminish the Intensity of Sound: But as Glasses may be fitted so as to magnify and diminish the Appearance of Objects, so likewise are Instruments to be formed for magnifying or diminishing Sounds, when there is Occasion for it, which not very rarely happens.

Euphros. Such Instruments, I suppose you mean, *Cleonicus*, as are called *speaking* and *hearing* TRUMPETS; the former of which magnifies the Sound of the Voice, and thereby occasions it to be heard at very great Distances: For which Purpose, I know, they are of very great Use at Sea, in transmitting the Voice in an audible Manner from one Ship to another, which would otherwise be impossible to be heard. The latter, I observe, are used by People who are very deaf, in order to magnify common Sounds upon the Organ of Hearing.

Cleon. It is very true, my *Euphrosyne*; the Speaking-trumpet is analagous to a magnifying Glass, or Speculum, in Optics, which makes the Image of an Object bigger than the Object itself; so the Speaking-trumpets are constructed in such a Manner, as to magnify the Sound of the Voice; for the Force of the Voice, naturally, is, spent upon all the circumambient Air; whereas, by Means of the Trumpet, the whole Force of the Voice is made to act upon that Quantity of Air only which is contained in the Tube of the Trumpet, by which Means that small Parcel of Air will be put into a much greater Motion, and have its Vibrations excited and rendered much stronger than they could otherwise be at a given Distance from the Mouth. Thus, for Instance, at the Distance of the End of the Trumpet, the whole Force of the Voice agitates the Air only contained in the Area of the said Trumpet's Aperture: Whereas, without the Trumpet, that Force is diffused into a whole spherical Superficies, whose Diameter is twice the Length of the Trumpet, which Superficies may be 400 Times greater than the Aperture of the Trumpet; and therefore the Intensity, or Strength of the Voice, will be so many Times increased, or magnified by the Trumpet. Hence, by Means of such a Speaking-trumpet, People at a Distance can hear us to the same Advantage as they can see us by the Use of a Telescope.

Euphros. After the same Manner, then, I presume, a Person who is hard of hearing has this Organ, or Sense, assisted by a Trumpet of nearly the same Form; for as the Vibrations of the Air are too weak to produce an audible Sound on such an Ear distinctly, therefore a Trumpet, being applied to the Ear, receives the languid Pulses of Air, and, by a constant Repercussion and Agitation of the Air in the Tube, heightens and increases its Force in Proportion as the Space becomes less, or the Tube is narrower, till it reaches the Drum of the Ear, where it becomes so great as to render the original Sound of the Voice distinct and audible to that deafened Organ.

— This Effect, I apprehend, is similar to that of visual Glasses to a deficient, or long-sighted Eye: So that, by the Assistance of Art, both the Organs of Sight and Hearing may, when deficient by Age, receive considerable

considerable Improvements, and, as it were, a Renovation to the End of Life.

Cleon. Before we leave this Subject of magnifying Sounds, I must put you in mind of the Whispering-gallery in *St. Paul's*, which gave you so much Surprize and Entertainment when you was last at *London*. You then heard a Voice so loud and distinct as if the Person was within the Distance of a few Feet; whereas, he was really at the other Side of the Gallery, and his Voice emitted in Whisper so low as not to have been heard by you near him, had it been expressed in a Room of a common Form. But this small Force of the Voice, being impressed upon the Air contained in the Room, or Space above that Gallery, was greatly increased, by a constant Reflection and Reciprocation from the spherical Surface of the said Dome, and became as it were at Length converged and condensed on the Drum of the Ear, which, though at the Distance of the whole Diameter of the Dome, are rendered sufficiently strong to excite the Idea of every Word that is spoke.——But, after all, it must be confessed, that few of our acoustic Writers seem to understand the Cause of this Phænomenon, and to explain it with that Clearness and Satisfaction, as Opticians do with respect to the Microscope, for magnifying the smallest Objects, or rendering them very distinct to the Eye.——I shall mention only one Instance more, in which there is a Similarity between Light and Sound, *viz.* in regard to Velocity; but in this though the Velocity of Sound be exceeding great, yet it bears scarce any Proportion to the Velocity of Light; for the latter cannot be rendered sensible, or measured by any common Experiment. However, by some Observations of the new and improved Astronomy, the Velocity of Light is found to be about 12 Millions of Miles *per Minute*: Whereas, the Velocity of Sound is found, by unexceptionable Experiments, not to exceed 1142 Feet *per Second*: And hence it is, that we find a considerable Time intervenes between seeing the Action, the Stroke, or Explosion of a Gun, and hearing the Sound thereof, *viz.* so many Seconds as the Number 1142 Feet is contained in the Distance between us and the Object that emits the Sound.

Euphros. If this be the Case, it must be easy to measure the Distance of an Object by measuring that Interval of Time, which, I suppose, you can very readily do by Pendulums.

Cleon. Yes, very easily, my *Euphrosyne*; and for that Purpose I have here provided you a *half-second Pendulum*; for by that alone you may very nearly measure the Distance of a Cloud, at any Time, when it thunders and lightens: For Instance, the next Thunder-storm, you hang up the Pendulum on a Pin, and hold the Bob in your Hand ready to let it go upon seeing the Flash; then, telling the Number of Vibrations which are made between that, and hearing the Clap of Thunder, you have measured that Interval of Time in Half-seconds; half that Number is the Number of whole Seconds, which the Sound takes up in coming from the Cloud to the Ear, to each of which you allow 1142 Feet, and, consequently, you thereby know the Distance of the Cloud in Feet to a great Degree of Exactness, and which, indeed, cannot be found so truly in any other Way.

Euphros. I am obliged to you for this little Instrument, and shall put it in Use, according to your Direction, the first Opportunity that offers.

D I A L O G U E VII.

*Of the PROPERTIES of SOUND, with respect to
MUSIC, or HARMONY.*

Cleoniceus.

WE have hitherto considered the Properties of Sound which result from the Manner in which they are generated and propagated; and as Sound consists wholly in the vibrating Motion of the Air, it was natural to observe, that the different Forces by which those Pulses strike the Drum of the Ear, will raise those Ideas in the Mind which are expressed in the various Degrees of *strong* and *weak* Sounds, or otherwise distinguished by *loud* and *low*; for in Proportion as the Force is greater

on the Membrane of the Ear, so the Sound will ever be stronger or louder, and *vice versa*.

Euphros. This I can very easily understand:—— But what are those Affections of Sounds which you call their *Notes*, or *Tones*, with their various Distinctions, as I find them in my musical Books? Something of this Kind I should be glad to understand, as I should be then said to join a little Theory with my Practice.

Cleon. You must not, my *Euphrosyne*, expect much to excel in both:——It is a Thing hardly ever known, that a Person was completely skilled in the Theory of Music, and, at the same Time, a great Proficient in Practice. I am very well informed, that HANDEL himself knew but very little of the Philosophy of Music, at least the mathematical Part thereof.——What you enquire after now, are the first Principles of natural Music, and they are extremely easy and sensible to what we may properly call an *harmonic Ear*; but to others, they have but very little Distinction, or Meaning: Such People hear Talk of the *Seven natural Notes of Music*, as a blind Man may of the seven different Colours of Light; for in neither Case can any distinct Ideas be formed of the Objects: But an Ear like your's, naturally formed for hearing Sounds, will readily apprehend what is meant by their Tone, or Tune, with all their Differences and Gradations. You will then, in the first Place, consider, that the human Mind is naturally disposed to be pleased and delighted with some particular Modifications of Sounds above others: Thus the Sound of a String, properly strained and struck with a Quill, is generally very agreeable to every Ear; but those who have a *musical Ear* will find the Tone of that String, when put in Motion by the Air, still much finer and more exquisitely pleasing, as you yourself may be thoroughly convinced of by the Experiment of the *Æolus's Harp*. But other Sounds are emitted from Bodies, which are as disagreeable and uneasy to the Ear; as in the Case of whetting a Saw, &c. where we are to observe, that all the Degrees from the most grating to the most pleasing Sound arrive principally from the Manner, in which the same Body is struck, or put into Motion: The finer and more delicate the Touch, the more delightful and exquisite the Note
that

that ensues, as we, by Experience, find in the *Violin*, the *Spinnet*, the *Lyrichord*, the *Dulcimer*, and the *Æolian Harp*: —Also, if a Glass be properly struck with a Wire, it will emit a pleasant Sound; but if it be artfully touched with a Finger a little wet, the Sound will be still much finer and more agreeable; from all which we may collect, that all we mean by the *Notes*, or *Tones* of Sound, is such a Modification thereof as renders them more or less agreeable to the Ear.

Euphros. I believe I understand you in all that you have said, and, therefore, suppose that these Sounds, emitted from Bodies, which are most agreeable and pleasing to the Mind, are such as you call *harmonical Sounds*, or musical *Notes*, and of which the Musicians serve themselves in their various Compositions.—But what is that you call *Concord*, or *Discord*, in Sounds?

Cleon. By *Concord*, is meant the pleasing Agreement of any two or more Sounds, or Notes; and by *Discord*, of Course, we mean the disagreeable Effect of two or more Sounds, upon the Ear, following each other in Succession: For the Mind of Man is also naturally formed to receive Pleasure from a certain Succession of Sounds, or such as follow each other at proper Intervals; and for this Reason they are called, the *musical Intervals of Sounds*: But when Notes, or Sounds, succeed in a different Manner, and at other Intervals, then they become inharmonious and disagreeable. And it now remains, that I shew you what Kind of Intervals of Sound, in Succession, are of a musical Nature, and on what Principles they depend.—The easiest Method for this Purpose will be, that of a String properly strained on a Board, on whose Vibrations each Tone will be found to depend: Accordingly, I have here provided you with several of those Strings, of different Sizes, Length, and Degrees of Tension; for you must observe, that according to the Time in which a String vibrates, its Note will vary with respect to high or low, or what the Musicians call *Grave* and *Acute*. For Instance; the Wire you see here, being strained pretty tight, emits a Sound when I strike it with a Quill, which is considerably strong, high, or acute:—

—ut now I will relax it a little, and then, striking it,—

—you readily observe the Difference there is in the Note,

viz. that it is now much lower, or more grave as they call it; and this Variation, with respect to grave and acute, depends, as I said, on the different Time of the Vibrations of the String; for you must know, that the Vibrations of a String are analogous to those of a Pendulum, and are all performed in equal Times, while the String continues in the same Circumstances: But the Times of the Vibration of the String will be varied according to its *Size, Length, or Tension*. Thus for Illustration, suppose two Strings of equal Lengths, and stretched with equal Weights, but the Quantity of Matter in one just double that of the other, then the Time of one Vibration of the largest will be just double to the Time of a Vibration of the Lesser, and the *Note or Tone* will be twice as *low*, or more *grave*, in the first than in the last.

Euphros. This I readily apprehend, from the Experiment; for striking the two Strings successively, I find that which has the least Diameter has a Note or Tone higher than the other, by what is called an *Octave*: — But now I have mentioned that Term, I should be glad if you would give me some hint of the Etymology of it.

Cleon. By the word *Octave*, the Musicians denote such an Interval in the Tone of musical Sounds as contain all the seven natural Notes of Music, as they are called, and which are employed as the Materials of all harmonical Compositions: And the several Intervals of these Notes, you know, are included between the two Extremes of the *First* and the *Eighth*, which whole Interval of musical Notes is therefore called an *Octave*.

Euphros. The practical Part of your Doctrine I know very well; for on my Harpsichord, when I strike the Key C, it is what my Master has taught me to call the *Chord*, or *Key Note*, in reference to which others above and below have different Denominations, according as they are higher or lower. Thus the six following Notes above D, E, F, G, A, B, and those below the *Chord* are of the same Name in a contrary Position; so that what is called an *Octave*, I find, is the Extent of these seven Notes, taken either Way, upon the Keys of the Harpsichord; and as the Strings belonging to those different

different Keys have different Notes or Sounds, I presume you will next explain to me the Reason why these are made choice of, in Preference to any other which are contained in the same Interval, or *Octave*.

Cleon. I shall give you the Reason of that by-and-by; but I must now proceed with the *Rationale* of the grand Interval or *Octave*; for, as I told you, this Interval in the Sound of Bodies is procured in Strings three different Ways; the first of which is, the Experiment under Consideration: You see, by this, the Notes are in Proportion to the Quantity of Matter inversely, so that a String twice as big as another will have a Note twice as low, all Things else being equal:——But the same Difference in the Tone or Sound of Strings (that are among themselves of equal Weight and Length) is procured from a different Degree of TENSION; for if two equal Strings be placed near each other, as you see here on this musical Board, (or *Tonometer*, as it may be called) and then stretched with equal Weights at the End, there will be no Difference in their Tone.——For Instance, you see, I hang a Pound Weight to each, now strike them with your Quill.

Euphros. I do,——and find the Tone or Tune of each String exactly the same, or *Unison*.——But now, pray, how much Weight must you add to one of them to make the Difference, or *Octave*, as before?

Cleon. Here you must know, the Mathematicians have found by the Rules of their analytic Art, that the Tones or Tunes of Strings are higher in Proportion to the Square Roots of the Weights, or Forces by which they are stretched; so that if I would raise the Notes of one of these Strings, an *Octave* above the other, or to make it sound a Note twice as high, or more acute, then it must be stretched with a four Pound Weight (because twice two is four), and this you see will be verified by Experiment; for to the one Pound which now gives it a Tone equal to the other, I will add three Pounds more,——which I have done: Now strike them as before.

Euphros. Well, this is a very curious Experiment truly:——The Difference in their Tone is accurately an *Octave*.——From this Experiment I see the Reason

of tuning the Harpsichord, by stretching their Strings more, or less, to raise their Notes higher, or lower, by turning the iron Pegs with my Hammer till I have produced the Note desired; for as the Tone of a String depends on the Degree of its *Tension*, the Manner in which we stretch the String will make no Alteration:—

—But, according to this Doctrine, by hanging on different Weights, to the same String, you could produce all the different Notes contained in the *Octave*.

Cleon. Yes, with Ease; for Weights adjusted and determined by the above Rule, being appended at the Ends of seven equal Strings, will produce you an *Octave* of the seven natural Notes of Music. Thus for Instance: If eight equal Strings are stretched by Weights which are in Proportion to the following Numbers, which may be considered as Ounces, *viz.* 60, 75, 94, 106, 135, 166, 210, 240, then will their Notes or Tones be those required, for constituting a musical *Octave*.—But there is yet another, or third Method, by which the same Difference is produced in the Sounds of Strings, and that is, the Difference of their LENGTHS; for two Strings, in all other Respects equal, having their Lengths as 2 to 1, will have their Notes inversely, or as 1 to 2, that is, the Note of the shortest String will be twice as high as that of the longest.—This I have likewise provided you an Experiment to prove; for of the two Strings which before were stretched with equal Weights, *viz.* a Pound each, one of them still continues the same; but the other I have made of half the Length, by putting a Bridge under the middle Point of the String, to stop the Vibrations, or confine them to half the Length: and now, though the Strings are stretched with equal Weight, and are of equal Magnitude, yet, upon striking them, you will find they emit very different Sounds.—Try the Experiment.

Euphros. I will:—And as in the two former Cases, so in this, there results the Difference of an *Octave* precisely in their Sounds.—Since this is the Case, I readily conceive that all the natural Notes of the *Octave* may be produced by proper Lengths of Strings between these two, which Lengths, I suppose, are not difficult to be assigned by the mathematical Musician.

Cleon.

Cleon. Nothing is more easy; for which Purpose, it is customary to divide the Length of the longest String into 100, or 1000 equal Parts, which, you see, is here done upon the Board, or *Tonometer*: This Line so divided is called the *MONOCHORD*, or *Base-Note* to the rest of the *Octave*, or the *Key*, with Regard to any particular Air or Species of Music.——Now, by the Rules of *musical Arithmetic and Geometry*, the Numbers, or Divisions of this Line, are easily assigned for giving the Lengths of the Strings to sound the seven Notes above the Bass; and by placing the Bridge against those Numbers, this other String may receive all those various Lengths, and will accordingly emit the several musical Sounds required; those Numbers are as follow, *viz.* 500, 533, 600, 666, 750, 800, 888, 1000; so that, for Example, if I stop the String with the Bridge placed against 500, it gives but half the Length of the Monochord, and sounds an *Octave* above it, as you have heard.——If I place the Bridge against 533, it gives the Note which the Musicians call the *Seventh Greater*:——If the Bridge be removed and placed against 600, its increased Length will give the Note called the *Sixth Greater*:——If stopped against the Number 666, it gives the *fifth* Note, or *Diapente*, as the Musicians call it:——By placing the Stop against 750, you have the *Diateffaron*, or *fourth* Note above the Key——By stopping the String at 800, you have that remarkable Concord called the *Third Note* above the Base:——and, lastly, by placing the Bridge against 888, you have the Note called the *Second Greater*; the Key Note being the whole 1000: And thus, you see, all the seven natural Notes on the same String are produced by stopping at those musical Divisions of the Monochord.

Euphros. Indeed, this has given me a more clear and distinct Idea of this famous musical Division, the *Octave*, than ever I had before: But there is one thing I observe in your Expression of these Notes, which naturally excites the following Query, Whether the *Seventh Greater*, the *Sixth Greater*, *Fourth*, *Third*, and *Second Greater*, do not imply that the same Notes may be also *Lesser*?

Cleon. Yes; that you will conclude of Course; for, in the musical *Octave*, those Notes mentioned may be made higher or lower, by half a Note; that is, with Regard to the Bass Note, the third Note above, for Instance, may be made a little higher or lower, according as the Air of the Music requires:——The Higher is called the *Greater*, and the Lower is called the *Lesser*: But you will better know and distinguish these Differences by other Names that you have been more used to, *viz.* FLATS and SHARPS; for a flat Third is a Third Lesser, and is the very same with the Sharp Second, or Second Greater: Thus also the Flat Sixth is the Sixth Lesser; but it is nothing more than the fifth Note made half a Note higher or sharper: But the same fifth Note made half a Note lower, or flatter, becomes the Fourth Greater, and so of the rest. Hence it is that in any musical Compositions those Notes may be adapted to the Nature of the Harmony, or Species of Music: Thus, for Example, in all grave and solemn Airs, the lowest and deepest Notes of Instruments are generally used; but in brisk and lively Strains the higher Keys on the Harpichord are mostly employed. If the Air be of the mournful, or elegiac Kind, those Notes are lowered, and the Music is said to be composed in a *Flat Key*: But in Odes and Songs, whose Subjects are Love, Mirth, Joy, &c. then the *Musician* in a *Sharp Key* tunes all the Strings to their highest Notes, and renders, by that Means, the Harmony as chearful as possible.

Euphros. You are now within the Compass of my Comprehension, I understand all you have said with respect to Flats and Sharps: By those half Notes, I observe, you mean those five secondary Keys that lie between the common Keys of the Spinnet, with their black and white Surfaces, by which we render any of the natural Notes, or Keys, between which they are placed, flatter or sharper, at Pleasure; so that these five being added to the other eight, make thirteen half Notes in the *Octave* inclusive.

Cleon. This Variety of Notes in the flat and sharp Keys make the common GAMUT, or *Diatonic Scale of Music*; and several of these repeated are contained within the Compass of many Instruments, *viz.* the Spinnet, Harpichord, Lyrichord, Organ, &c.

Euphros.

Euphros. Of these Notes, the *Octave*, *Fifth*, and *Third* are a Sort of governing ones, or have the principal Regard in every Composition: Pray, on what Account are they intitled to this Pre-eminence?

Cleon. On account of their being the most perfect Concords in the Scale, *i. e.* their Sounds, succeeding the *Octave*, have a more agreeable Effect upon the Ear than the Sounds of other Strings: The natural Reason of which is owing to the Frequency of the Coincidencies of their Vibrations; to make which Doctrine as plain as possible, I must observe to you what I before mentioned, *viz.* That the Tune of a String depends upon the Time of its Vibration; therefore, the shorter the Time of the Vibration, the higher the Note will be; and in Vibrations that are performed in different Times, there will, at certain Intervals, be a Coincidence of those Vibrations in all of the musical Kind: Thus, for Instance, if two Strings vibrate in equal Times, then the Vibration of one must constantly coincide with that of the other, and they produce a MONOTONE, or UNISON, in which there is no Variety; and consequently two such Strings can make no Harmony. But if we consider that String which is called an *Octave*, as its Tone is twice as high as that of the Key-note, so its Vibrations are twice as quick; and consequently there will be a Coincidence of Vibrations at every second Vibration of the *Octave*, or every single Vibration of the Monochord. Now, as this interval is the shortest that can be between any two Strings in the same *Octave*, therefore, the Effect of such Coincidence will produce the most agreeable Concordance of Sound, or (in other Words) will constitute the most perfect Concord in musical Sounds.

—Again, the *Fifth* Note being sounded from the String whose Length is two-thirds of that of the Monochord will vibrate three times while the Monochord vibrates twice; so that there will be a Coincidence of Vibrations at every Second of the latter, which Interval, being twice as great as the former, is not so perfect a Concord as the *Octave*, but is yet next to it in its agreeable Effect and Perfection of Harmony: —Then if we consider the *Fourth Note*, the String which sounds it is three-fourths of the Length of the Monochord, and therefore

therefore will vibrate four times to every three Vibrations of the latter ; therefore the Interval of Coincidence will be now three times as long as in the *Octave*, and consequently will, in Comparison of that, be a much less perfect Concord :——But when we consider the Length of the String that sounds the *Third*, we find it in Proportion to the Monochord, as 8 to 10, or as 4 to 5, and the Interval of Coincidence of course will be at every fourth Vibration of the Monochord, and therefore, in itself considered, not so perfect a Concord as the fourth ; yet its Effect is found, in musical Compositions with other Concords, much more agreeable than that of the *fourth* Note, and therefore is esteemed by Musicians as the third musical Concord. This is the general Principle or Ground of *Concord* ; those Notes being reckoned *Discords* whose Pulses, or Vibrations, rarely coincide with those of the Monochord, as thereby they produce a more dissonant and less agreeable Sound.

Euphros. As the Tones of Sounds depend on the times of the Vibrations, I should be glad if my Curiosity could be satisfied with regard to the greatest Extent of Note, or Sound, which Bodies are capable of emitting, or which the Ear can well bear.

Cleon. An Answer to this Question requires more Experience in musical Sounds than I can pretend to : But a certain Gentleman abroad, Mr. SAUVEUR, has made great Numbers of Experiments on the Vibration of musical Strings, and consequently of musical Sounds ; has found that such Sounds as can be heard distinctly and with Pleasure, and in whose Tone a Difference can be clearly perceived by the Ear, lie within the Compass of ten *Octaves* ; and if we include the lowest harmonic Sounds, on the one Hand, that can be heard, and the highest that the human Ear can bear, on the other, they will all be contained within the Limits of twelve *Octaves* : and if this be the Case, it follows, that the Body which gives the shrillest Sound that the Ear can bear, makes 4096 Vibrations in the time that one Vibration is performed by that Body that gives the gravest harmonic Sound, and that $12\frac{1}{2}$ of these Vibrations are performed in one Second ; therefore the Vibrations of the shrillest sounding Body will be 51100 in the same time ;

time; so great are the Motions of the Parts of Bodies produced in exciting such very quick Vibrations.

Euphros. As this is the Case, I do not wonder at an Effect which I have often heard of, that is, the breaking of a Drinking-glass by ringing of it, or raising its Tone higher and higher; for, by this Means, having its Parts put into such a violent vibrating Motion, it is no Wonder if they are shaken in sunder, and fly into Pieces.

Cleon. I could very easily shew you this Experiment, but do not think it safe, the Note being at last so exceeding shrill and acute, that I fear it might have a bad Effect on the Drum of your Ear, as it is but too well known that many People have been hurt by such Kind of Sounds.

—However, I shall substitute a very innocent one in its stead, which will sufficiently show the prodigious Degree of Vibrations, and the vast Extent of Tone the Substance of Glass is capable of. —You see here a very large Glass, of a Bell-form, provided for the Purpose, into which I pour Water to fill $\frac{3}{4}$ Part: —Then, dipping my Finger in the Water, I gently pass it round the Rim of the Glass, and thereby excite, first, a very pleasant grave and musical Sound; but, as the circular Motion of my Finger continues, the Vibrations of the Glass are increased, which becomes extremely sensible both to the Ear and to the Eye: for you hear the Tone still more and more intense and acute, and you see its prodigious Effect on the contained Water, in which it first produces Undulations, then very quick Gyration; at length, there appears such an Agitation as may be compared to a Kind of Hurricane, throwing with the utmost Violence, the Particles of Water into the Atmosphere all *around*, and to a great Height above the Glass: —and still might we raise this artificial *Tempest* to a greater Height, but that I see the Tone of the Glass has a greater Effect upon you already than you can well bear.

Euphros. Indeed, I cannot help shrinking, as it were, from it; but am pleased to see the wonderful Effect it has in the Body of Water, in these turbulent Emotions which it occasions, such as we could scarce have supposed, or believed, if they had not been evinced by Experiment: —

But

But I shall trouble you no longer, at present, as you propose, at our next Meeting, to explain the *Rationale* of the general Part of musical Instruments.

DIALOGUE VIII.

The Rationale of different Kinds of MUSICAL INSTRUMENTS, considered.

Euphrosyne.

I Have pleased myself with the Prospect of the present Opportunity of being instructed in the Nature, Construction, and *Rationale* of musical Instruments; which you informed me was to be the Subject of our Conversation at this Time. You have always known my Disposition is such, as to be equally inquisitive after the *Reason*, as well as the *Practice* of every Art I delight in; as I have always looked on it as an Argument of Indelicacy, and want of Taste, in those who are wholly occupied in learning the mechanical or practical Part of an Art, with a View to sensual Entertainment only, without regarding the sublimer Pleasures that arise to the Mind from a Contemplation of the Principles which constitute the Theory, or Reason of the same.

Cleon. I was ever glad to see such a Turn of Genius in you, and every one else: Though, as I have hinted to you before, the Principles, or Theory of Music are not quite so obvious as those of any other Sciences; yet, as they principally consist in the Doctrine of Vibrations of the constituent Parts of Bodies, if this were well attended to, and properly explained and illustrated by Experiment, you yourself are a Proof, my *Euphrosyne*, that they fall within the Comprehension and Capacity of the Fair-sex; and how delightful, as well as graceful, is it both in common and sacred Music, to see and hear a Gentleman or Lady not only play with their Hands, and sing with their Voice, but with their Understanding and Judgment also?

Euphros.

Euphros. I have great Ambition to excel in both, as far as I am able:——I pretty clearly understand what you have hitherto said in regard to the vibrating Parts of Bodies:——That Sounds in general are occasioned by the Pulses of Air produced by those Vibrations:——That musical Sounds in particular are such as have a delightful and melodious Effect upon the Ear:——That Concords and Discords proceed from a greater or less Frequency of the Coincidence of those Vibrations in sounding Bodies:——From these Principles I can easily infer, that all Kinds of stringed Instruments, as also Glasses, Bells, and other sonorous Bodies, are capable of emitting harmonious Sounds; and of Course, by the Rules of Art, may be formed into musical Instruments; But how, and in what Manner this is done, I cannot pretend as yet to have so clear an Idea of, and therefore shall beg your Assistance in these Points of Information.

Cleon. With respect to stringed Instruments in general, the Principle of their Construction is this, that as they consist of several DIAPASONS, or OCTAVES, so they afford three different Degrees of musical Notes, the *Treble*, *Tenor*, and *Base*; the first of which contains the Notes of the highest and most acute Sounds; the Second, or *Tenor*, those of a mean Degree of Sound; and the last, or *Base*, those of the lowest or gravest Order. And, according to the Form and Extent of the Instrument, the Strings which compose the several *Octaves* are modulated and fitted to emit their proper Notes, or Sounds, by one or other of the three Ways that I mentioned to you in the last Conference; for, as I then shewed you by Experiment, the Instrument-maker has it in his Power to produce any given Note in a String in any of those Ways, as Occasion or Necessity requires; or he can raise or lower the Note by a smaller or a larger String of the same Length:——By a shorter or longer String of equal Size:——And, lastly, by giving a different Degree of Tension to one and the same String: And thus in all the Instruments where the Strings are to be of a fixed and determinate Length, as in the *Dulcimer*, *Spinnet*, *Harpsichord*, the *Lyre*, the *Lyrichord*, &c. the Strings of the various *Octaves* are always adjusted and tuned in this Manner.

Euphros.

Euphros. This I apprehend pretty easily, with regard to the Instruments that I have every Day before my Eyes; in these, as the *Octaves* and Strings in each are of a given Length, or invariable, if they are once put in Tune, a Person has nothing to do but to get the fingering Part, and he must necessarily play the Tune by striking the Keys proper to the Notes of the Music: But this seems to me, though a very fine Species of practical Music, the most mechanical of any.

Cleon. It is so, to be sure; since it is possible for a Person, without any Ear or Genius for Music at all, to learn to play on those Sorts of Instruments, after a Manner: But mechanical as they are, no fine Music can be produced from them but by a curious Hand and judicious Ear. However, it must be confessed, that other Sorts of stringed Instruments are, in their own Nature, of a more curious and artful Construction, and of a more universal Nature.

Euphros. I suppose you mean, by these, all that Class of Instruments comprehended under the general Names of Violins, Harps, &c. I cannot say there is much of a Wonder in producing such a Variety of Notes from a Harpsichord, where there are such a Number of Strings; but I have oftentimes very much wondered how they produce such a Variety of Notes, and play an Infinity of Tunes, on an Instrument of so few Strings as that of a Violin, for Instance.

Cleon. The Wonder here will soon cease if you consider, that an infinite Variety of Notes may be produced from a single String; for it affords as many different Notes as Points in which you can stop it: Thus, for Instance, if you stop it in the middle Point, you have a Note which is an Octave above that which is produced by the String at its whole Length: If you divide the remaining Part into two equal Parts, or stop that in the middle Point, then, striking that 4th Part with the Bow, it will emit a Sound which is a double Octave, or sixteen Notes above the Base Note, or that of the whole String; This 4th Part being again divided or stopped in the Middle, produces a 3d Octave of Notes; and supposing another String of a different Size added to this, you have, by stopping that in the like Manner, other Octaves

pro-

produced, all differing from the former; and so of a third and fourth String: And therefore, in the Violin of four Strings, a skilful Musician may extend his Scale of Music to 8 or 12 Octaves, or even farther if there was Occasion, by properly stopping the Strings: But in this Case, there must be Velocity and Judgment at the Finger's End, such as is required for performing all the different Kinds of Music. The former of which is attainable only by Practice, and the latter by the Assistance of a good Ear, naturally constructed for a nice Discernment of musical Sounds. On these Instruments, Nature is the sole Mistress in the School of Music; and it is surprising, to find what Proficiency some Pupils have been seen to make in this seemingly difficult Part of the Art: But it is in Music as in Poetry; if Nature dictates, her Lessons are very plain and easy, and give us no trouble either in learning or practising. The Poet writes Verses, perhaps, more naturally and elegantly than he can talk in Prose; and the Musician plays the most difficult Pieces with so much Ease, as if they had acquired this Knowledge before they came into the World, according to the ancient Doctrine of Transmigration of Souls.

Euphros. All you observe, I think, is very just, and it gives me a clear Idea how an Instrument of a small Number of Strings might be of an unlimited Extent in Music, while one of a much greater Number is perfectly confined: But, pray, *Cleonicus*, can you solve me one Query on this Head, viz. how it is possible to produce all the natural Notes in a musical Octave by one Stroke of the Bow, and the same Length of the String; for this I actually saw and heard from a very skilful Musician the other Day?

Cleon. I have likewise seen and heard the same Thing; it is a Paradox in Music, I allow, and has been strongly denied by many who have not been convinced by the Fact: It is true, the three Principles, viz. the Length, Tension, and Diameter of the Strings, are those which in general cause any Variation in the Notes of sounding Bodies; but, from this and many other Experiments, it is very certain there are other less evident Causes which concur in producing that Effect, such as the greater or
lesser

leffer Degree of Pressure on the String, in the Motion of the Bow over it; also, the Distance from the End of the String, at which it is touched; as likewise, the greater or less Pressure of the String by the Finger; and some other Circumstances may enable a Person, with a good musical Ear, to vary the Sound of the String in the Manner before mentioned.

Euphros. You observed to me, in speaking of the Harpsichord, that the Octave there was limited to thirteen musical Notes, inclusive; but in this free and unconfined Instrument, the Violin, I presume, the Musician has a larger Scope, and may be more critically nice in the Division, or Choice of his Notes, and thereby render his Music more refined and harmonious.

Cleon. What you observe is very just; but for this Purpose, a Man must have a very nice and critical Ear: For, when you go beyond the common Flats and Sharps, it will not be easy for an ordinary Practitioner to know where or how to stop in Tune, or to make them more or less flat or sharp than he has been taught by the common Gamut, or Scale of Music. Your great Performers, and Masters in this Science, extend their Scale to thirty-two Notes, inclusive, by raising, or depressing each of the natural Notes to such a Degree as only their Judgment and natural Skill can direct; and, in this Respect, can even transcend the musical Proportions of Geometry itself. These stringed Instruments, therefore, properly fretted or stopped, are capable of all the Variety that can be produced in the Science of Music and Harmony.

Euphros. You seem to be more than commonly pleased with the Structure of the LYRICHORD, as I have often observed from the Manner in which you make mention of that Instrument; and, by what I have seen of it, it seems more perfect in its Nature than any common Harpsichord: Pray, what are the Peculiarities of this musical Construction?

Cleon. It partakes of the Nature of the Harp and the Violin, and is possessed of the principal Properties of both, and, at the same Time, exempt in a great Measure from the Imperfections of either: It has, indeed, a certain or determinate Number of Strings, with Keys
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proper to each, like the Harpsichord ; but, as you observe, those Strings are not struck by Quills in the Jacks, but are brought down to the Surfaces of small Wheels, which move with great Velocity under them, and by this Means they are susceptible of a Stroke from the Wheels, in the same Manner as the Strings of a Violin are from a Bow, and therefore may, in a like Manner, have the Note produced, or contracted, as the Nature of Music requires: Whereas, in the Spinnet, or Harpsichord, the Notes are but of a momentary Duration, being stopped by the Cloth on the Jacks as soon as they are excited.——By this Opportunity of extending, or swelling out the Note, they make the Harmony more full or sonorous, not altogether unlike those noble and high sounding Notes of the Organ itself.——But even in this Instrument, unless it be furnished with split Keys, as they are called, you are still confined to the imperfect and scanty Divisions of the common Gamut.

Euphros. But there seems to me an Apparatus in this Instrument which I have never observed in any other, and that is of a great Number of Leaden-weights, very curiously and artificially disposed in the Fore-part of the Instrument, which I am informed, is for keeping the Strings constantly in Tune:——What have you to say in regard to this Contrivance, *Cleonicus*?

Cleon. I think it a very curious and philosophical one; for, by Means of the large Weights, the Strings of each, respectively, have their due Degrees of Tension, proper to the Places they hold in each Octave: And by the Screws in the Mechanism for moving the lesser Weights, the Tone of each String is adjusted to the nicest Ear; and when the Strings of the Lyrichord are once put in Tune, they must necessarily continue so, as the same Weight, always acting uniformly, must produce the same Degree of Tension: This in a given String must always produce the same Note, and is the most excellent Property of this new constructed Instrument, and quite peculiar to itself——Though this Invention might, without much Trouble or Expence, with a little Alteration, be applied to the Harpsichord and Spinnet, and thereby prevent the very frequent Trouble and Expence of tuning those Instruments.

Euphros. I could wish with all my Heart, this was once done; for as I am not likely to be Mistress of a Lyrichord very soon, I should be glad if that Instrument which I have could be contrived to be kept in Tune, without such a frequent and necessary Rectification: But pray, *Cleonicus*, in what Method would you propose this to be done?

Cleon. Were I a musical Instrument-maker, my *Euphrosyne*, I should attempt it in the Harpsichord in the following Manner:—— You know that the Tone of a String varies with the Quantity of the Weight by which it is stretched; therefore any Contrivance that would increase, or diminish the Weight hanging to the End of the String, in any small Degree, would be sufficient for keeping that String to its requisite Tone. Now it is well known that a Weight lying upon an inclined Plane will have its Force increased, or remitted, in Proportion as the Plain is less or more inclined; and therefore, if on the back Part of the Spinnet, or Harpsichord, proper Weights were appended to the Strings, and these Weights supported on inclined Planes, on which they might freely move, those Planes by a Single Screw in each might be elevated, or depressed to such a Degree, as that the Strings should be all of them exactly tuned, and of Course they must so remain.—— Thus, one Set of Weights would be sufficient to answer this Purpose; and the Application less cumbersome and expensive than in the Lyrichord*.

Euphros. Well, I find I must be content with my Harpsichord as it is, since it is likely that this Alteration will not very soon take Place:—But, pray, what new Species of Glas-music is that which of late has been the Subject of so much Discourse and Enquiry amongst the musical Virtuosi?

* In order to accommodate our musical Readers with a Print of this most curious Instrument, we shall here insert that which we formerly gave in the miscellaneous Part of the Magazine; as few of our Readers will have an Opportunity of seeing the Instrument itself, they may derive, from a bare Inspection of this, a sufficient Idea of its Nature and Construction, which we hope will prove no small Gratification.





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Cleon. Why, truly, my *Euphrosyne*, it is in this as in most other Cases, that new Things make a very great Noise, and are generally conceived in a magnificent Idea at a distant View: but, upon a nearer Approach, and nicer Inspection, they are seldom found to answer our preconceived Notions of them: I believe, many People think this to be the Case of our new *vitreous Music*.— But why do you ask my Opinion of it, when it cannot be supposed but you yourself are a proper Judge, as you have both heard and seen it?

Euphros. I was willing to know your Sentiments before I discovered my own: I confess, with respect to myself, it is as you say, the Fame of it seems to exceed its Merit; for the Performance, at which I was present, the first Time, fell greatly short of my Expectation; a Second, answered better: But, pray, *Cleonicus*, why was Water used in some of those Glasses, and others were played on without any?

Cleon. The Glasses will have their Tones altered, or varied, different Ways, such as make the Vibrations of a different Duration: for, as I observed to you before, the larger Glas has the slowest Vibration, and consequently the gravest Note; and therefore, in any Glas, if you can lessen the Bulk of its sounding, or vibrating Part, you will thereby raise its Note to the required Pitch: And this may be done two different Ways; the first is by putting Water into the Glas, which will lessen the Dimensions of the sonorous Part; for the Vibrations will extend no farther than to the Water, where they will entirely cease, and therefore, by putting more or less Water into any Glas, the Vibrations will be rendered of a longer or shorter Duration, and thereby the Glas may be tuned to any Note required.—The second Way is, by grinding the Glas on the Edge till you have sufficiently lessened its Quantity, to produce the Note designed; and this is the same Method, in Effect, they take for tuning Bells, by turning off so much from the Rim, or Surface, as is necessary for that Purpose.— And in each of these Ways the Glasses are rendered truly musical, or harmonious.

Euphros. One of those Performers, I observed, had all his Glasses standing singly before him, fixed down

to a Board :——— Another had them placed round a common Axis, one within another, in the Manner as Bells are placed about a common Axis for the Chimes of a Clock :——— The last of these Methods is, in my Opinion, much preferable to the former : But though I think the Notes from Glafs much sweeter and finer than those from a String, yet is the Music itself of a much inferior Nature, as consisting only of plain Notes, without admitting of any Shakes, or other Graces, which all common Instruments are capable of : Besides, this Sort of Music seems confined to very slow Time, as a temporary Stroking, rather than a momentary touching the Glafs, is here necessary, and therefore nothing of that Agility in fingering can here be expected, which so greatly distinguishes the Performers on other Instruments.

Cleon. All that you have now observed are certainly Facts, that will render this Music of no great Consequence among the greatest Geniuses of this Sort : It is more accommodated to Melody, or vocal Music, than to that of common Concerts : for as the Notes of Glafs are soft and flowing, they are over-powered and absorbed by the stronger and higher Notes of other Instruments. It is, however, a distinct Sort of real Music, which is more than can be said of the *ÆOLIAN HARP*, whose Notes observe no musical Proportion of Sound, though they are all of them, from the highest to the lowest, most exquisitely pleasing, or rather ravishing to the Ear.

Euphros. I know this by frequent Experience ; for the Harp which I have, and often apply under the Sash of my Window, fills me, as it were, with the Sensation of celestial Sounds and Harmony :——— And it is amazing to find how the Notes will successively arise from nothing, swell to the most exalted Tones, and then gradually die away :——— They seem sometimes very near at Hand ; at others, you hear them, as it were, from the remotest Distance.——— And I have oftentimes observed that, from a different Number of Things in the Harp, the same wonderful Variety of Sounds will arise.——— And, farthermore, whether all those Strings are in Unison, or tuned to the various Notes of an *Octave*,

no

no sensible Difference will arise in the Sounds which are produced from the Strokes which are made by the invisible Hand of Nature,

Cleon. What you say, my *Euphrosyne*, I have often experienced the Truth of myself.——And from these and such like Phænomena, it evidently appears to me, that we are not yet fully acquainted with the PHILOSOPHY OF SOUNDS, especially those of a musical Sort; and that they have many other Causes concurring to produce and vary them, besides the three mathematical Quantities, *viz.* *Diameter*, *Length*, and *Tension*, of *Strings*.——As a farther Proof of this, I shall entertain you with one Experiment more to shew how, and in what a surprizing Manner, musical Strings are affected by each other's Vibrations: To which End, I have here provided you with a sounding Box, and two Strings of equal Size and Length on the Top of it: If one of these, which I shall call A, be strained to any particular Degree, and then we begin to stretch the other, which I call B, (and is placed very near to A) then will the String A be quiescent, or at rest, under all Degrees of Tension in the String B when it is struck with a Quill, excepting that only which is the same with its own, and in that Case the String A will begin and continue to vibrate equally with the String B. The two Strings therefore, as they have equal Degrees of Motion, will produce an Equality of Sound when equally struck with a Quill: And hence we see the natural Cause of that Concordance of Sound which is called *Unison*. But the Motion which is given to the String A by the Vibrations of B only, will be very small, and therefore produce but a very faint and almost imperceptible Sound: Yet still the Sound is *audible* to a good Ear, and the Vibration is visible to a common Eye.——However, that these Things may be extremely sensible to you, I have placed a Microscope over the Middle of the String, wherein you will observe the Phænomenon to the greatest Advantage.

Euphros. I am greatly obliged to you, *Cleonicus*, for taking so much Care to instruct and improve me in the Knowledge of natural Things.——I'll try the Experiments successively; and first, while the Strings have

two different Degrees of Tension, I strike one of them, and observe the other has no Motion even to the Eye assisted by the Microscope:——But now, as I turn the Nut and gradually stretch the String B, I observe, as it comes nearly to the Tension of the String A, that the latter begins to move, till at length the Tremor increases, and shews the Vibration of the String not less in Appearance in the Microscope than $\frac{1}{4}$ of an Inch:

——And it is very curious to observe how this Space gradually lessens, as I increase or remit the Tension of the String B, above or below that of A, till on either Side it vanishes:——Indeed, I can plainly see the Motion in the String A with my naked Eye, and can even hear the Sound when that of B is stopped.——By this Method, I apprehended, a Person that has no musical Ear at all, may, with his Eye, assisted by a Microscope, put two Strings in Unison to the utmost Perfection.

Cleon. You observe very rightly, my *Euphrosyne*, and not only in Unison, but likewise in any other comparative Degree of Sound: Thus, if I take the String B away, and substitute in its Room another which I call C, of just half the Length of B, then you know, when they are under the same Degree of Tension, there will be an Octave Difference in their Tone; or the Sound of C will be an Octave above that of A.——But now what is very mysterious is, the Effect which the String C has upon the String A; for, when it is struck, it will cause the String A to vibrate in two equal Parts: That is, with respect to its Motion, the String A is divided in the middle Point, and each Half vibrates equally with the String C, and that middle Point is entirely at rest: A Thing, which the most acute Philosopher would never have surmised, had it not been demonstrated by Experiment, which it is two several Ways.

Euphros. This will afford me very great Pleasure indeed:——Could any one have thought that a String could possibly be put into Motion by two Parts, and yet at Rest in a Point between them, at the same Time!

Cleon. So it is, my *Euphrosyne*, and the following Experiment will evince the Truth of it——I cut 3 small angular Pieces of Paper in this Form and Size, (A)

so that they may conveniently hang upon the String; then I place one of them precisely on the Middle of the String A, and the other two just over the Middle of each Half of the said String:——Now, my *Euphrosyne*, I strike the String C in a gentle Manner, and you observe the two last mentioned Papers are instantly thrown off, while that in the Middle of the String A remains entirely at rest.

Euphros. I view the Fact with Astonishment; nor can it need any thing more than this simple Experiment to support it. But could it not be otherwise shewn by the Microscope as in the former Case?

Cleon. Very easily, my *Euphrosyne*;——for now I place the Microscope over the middle Point of the String A, and when you have placed your Eye over it, for the View, I will strike the String C when you give the Word.

Euphros. I have a perfect View of the String A, and without any Motion at all:——Therefore, now strike the String C:——Well, though I hear you strike it, I protest I see no Motion in the Part of the String I look at, any more than before; but it still continues at Rest.——Now let me view the Middle of each Half.

Cleon. I'll first place it over that Half which is by the String C:——Observe the String, and give me the Word.

Euphros. I see the String at present perfectly quiescent;——you may now strike it:——A Tremor seizes the String at once, and it is dilated into a very considerable Breadth, at least 4 or 5 Times as wide as its natural Size:——And will the other Half produce the same Appearance, *Cleonicus*?

Cleon. The very same.——I will place the Microscope over the middle Point of the other Half, and then you will be satisfied.

Euphros. At present the String appears at Rest, as before:——Now give the Stroke to the String C.——Immediately the String is all in Motion, with all the same Appearance as before.——I am doubly convinced of this wonderful Event, and should be glad if you will give me to understand how, and in what

Manner such wonderful Motion is communicated from C to A.

Cleon. It is said, by Philosophers, that as the String A can be affected only by the Pulses of Air excited by the motion of the String C, and those Pulses being of the same Length with the String C, therefore they can strike it only in half its Length at the same Time; and therefore, by this Means, can put it in Motion only in those two Halves; and so the middle Point of the String, having nothing to strike it, remains at Rest.——This is accounting for it in a Manner somewhat similar to the Thing I allow; but I will not answer for its being satisfactory to every scrupulous Mind:——But that this is a Fact in every different Length of Strings, where the shorter is an aliquot Part of the larger, is certainly true, and it will be worth while to give one Experiment more to confirm it:——Therefore, I have here provided two other Strings, A and D; the Length of A is 4 Feet, and that of D but one Foot; they are placed at the Distance of $\frac{1}{16}$ of an Inch distant from each other, and both begin at the same Line: When they are properly tuned, or the String D a double Octave, or 16 Notes above A, then, when it is struck, the Pulses of Air which it produces can be only one Foot in Length; these Pulses therefore will affect the String A in 4 equal Parts at once, and consequently divide the String in three equal Points between the two Extremes, which Points, together with the two extreme Points, or Ends, are all to be considered at Rest, while the four intermediate Parts, or Quarters of the String, do severally vibrate at the same Time.——And in order to prove that this is really the Case, nine of those small Pieces of Paper will be necessary, to be placed at every 6 Inches along the String A; for then, when the String D is struck with a Quill, every other Paper ought to be thrown off, and the rest remain on the String:——And this, you see, will be done by fixing your Eye attentively on the String A, while I strike the String D.

Euphros. How wonderful is the Sight!——The Papers alternately fly off and remain at Rest:——Those which go off, do it with such Violence and Suddenness, that it can scarcely be perceived by the Eye;——
while

while those at Rest appear not in the least to have been shocked. — I do not know that I ever saw an Effect in Nature so very stupendous, and, at the same Time, capable of being demonstrated in so simple a Manner.

Cleon. I shall entertain you with more of the Wonders of Nature in this Way at another Time: At present, I think I have kept your Mind sufficiently upon the Stretch, and therefore shall postpone the Consideration of those called Wind-instruments to the next Opportunity.

DIALOGUE IX.

The Rationale of different Kinds of MUSICAL INSTRUMENTS, continued.

Euphrosyne.

YOU have given me a large and particular Account of many Sorts of musical Instruments, particularly those whose delightful Effects are produced by the Vibrations of Strings; and you promised me, at the Conclusion of our last Conference, that the Subject of our next musical Speculation was to be the PHILOSOPHY of *Wind-instruments*: Of this Sort, I must confess, I have but a very slender Notion, and here, if you do not take Care, you will soon get out of my Latitude.

Cleon. I shall trouble you with nothing very mysterious on this Head; for all Kind of Wind-instruments, from the *Jews Harp* to the ORGAN, depend upon one simple Principle, *viz.* the vibrating Motion of condensed Air; for as all stringed Instruments produce their Effects by exciting Vibrations in the Air by the Vibrations of their Strings, so all Kind of hollow Pipes may have their contained Air impressed, and condensed by the different Force of the Breath, or Blast from the Mouth, or by other Means, and thereby the Action of that condensed Air variously modified, and which, communicated to the external Air, will be the Cause of as great a Diversity of

Vibra-

Vibrations therein, and consequently of musical Sounds or Notes, which, as I have shewn you, consist in nothing more than the Pulses of Air properly modified and modulated for that Purpose.

Euphros. Then I suppose, by what you say, *Cleonicus*, if a Person applies a common Trumpet to his Mouth, and puts the Air in Motion by the Force of his Breath, the Vibrations of that condensed Air will make a loud Sound: — Then a Person blowing through a Trumpet of the same Dimension with such a Force of Breath as will condense the Air to twice the Degree, will cause the Vibrations to be twice as quick, and, consequently, to produce in the external Air a Sound, whose Note or Tone shall be twice as high, or more acute than the other: And therefore the Tones, or Notes of those two Trumpets will be an *Octave* distant from each other: Am I not right so far, *Cleonicus*?

Cleon. You certainly are, my *Euphrosyne*: And if the second Person was to agitate the Air with a less Force of Breath, so that its Vibrations should be in Proportion to those of the other Trumpet, as 3 to 2, then would the Notes of the two Trumpets be that Concord called the *Fifth*. If the Breath be farther weakened, so as to cause but 4 Vibrations in this Trumpet to 3 of the First, the latter will be a *Fourth* above the former, and so on for a *Third*, *Second*, &c. whence it appears, that two Trumpets being sounded together, are capable of producing all the Variety of musical Sounds in common with stringed Instruments.

Euphros. So far I understand you pretty clearly, and, at the same Time, I see in general the Reason why a *TRUMPET*, *French Horn*, &c. is of itself a musical Instrument; because, by variously agitating the Air with different Forces of the Breath, any Variety of musical Notes may be produced by Succession, and, consequently, any Piece of Music may be performed in a single Part by those Instruments, and two of them together in Concert; and because of the Greatness of their Sound, or Loftiness of their Notes, this Sort of *Wind-music* is generally appropriated to all joyful and triumphal Occasions, and are particularly pleasing in the Gloom of a serene Night, and have their Effects greatly

greatly heightened by their Reverberation from an extended Surface of Water. In this Trumpet-music, the Air seems not to be confined or agitated in the same Manner as in those Pipes or Tubes we call *FLUTES*: Pray, how am I to understand the Effect of this Sort of Wind-instruments?

Cleon. The Air in the Body of any Pipe or Flute, will, by other Air forced in upon it, be put into Motion, and being thereby more or less condensed, will have such Vibrations excited as are proportionably quicker or slower; and these, by Means of the Holes producing similar Vibrations in the external Air, will cause all that Variety of musical Sounds, as before: But the Notes of those Sounds will be variable, according to the Bulk and Length of the included Column, or Cylinder of Air; for the larger the Tube or Pipe, the greater will be the Quantity of Air to be put in Motion by the same Force of the Breath, and, consequently, the less will be its Condensation, therefore the slower its Vibrations, the lower will be the Note or Tone of Sound which it emits. — But as one Length of String will produce only one Sort of Note, (with the same Degree of Tension) so one Body or Quantity of Air will be capable only of one Degree of Vibration, and therefore of producing only one Note, which, indeed, may be higher or lower, as the Force of the Breath may be stronger or weaker impressed. But what I now say must be understood to relate to the common Method of sounding those Instruments; for, if you please, you may blow with Force enough to cause Vibrations twice as quick in the same Body of Air, and consequently to make the Sounds emitted an Octave one above another: But you cannot, in this Case, produce any Note between the Octaves, which is something of a very odd and extraordinary Nature.

Euphros. Pray, *Cleonicus*, what is it makes that which is called the *Pitch-pipe* of such general Use in tuning musical Instruments?

Cleon. As we are now discoursing of Wind-music of the tubular Kind, your Question is very *apropos*, and the *Rationale* of the Pitch-pipe will be very easy to conceive from what hath been said: For as the Vibrations

of

of the Air will be proportioned to its Quantity in a uniform Tube, whether square or round, it matters not; therefore as you increase or diminish the Length of the Bore, or Capacity of the Pipe, by the solid Part that is moveable in it, so you may give such Lengths to the included Body of Air as shall render it productive of Vibrations of any given Degree of Velocity, and thereby produce any given Note of an Octave.

Euphros. If I understand you right, when the Air of the Pipe has its full Length, it will produce the lowest or *Base Note*; but when the solid Part is placed so far in the Pipe as to diminish the Length of the Body of included Air, by one Half, and the Note be sounded, it will be now an *Octave* above the former, or twice as high: Is it not so, *Cleonicus*?

Cleon. It is, my *Euphrosyne*, just as you have expressed it:—And furthermore, if the Stopple be moved still farther up the Pipe, so as to leave the Column of Air but $\frac{1}{2}$ of its first Length, its Vibrations will be then twice as quick as in the last Case, and therefore will produce a Note twice as high, and consequently will be a double Octave above the *Base Note*:—Therefore it is, that this solid Part or Stopple may be considered as a *Monochord* in its whole Length, and may be so divided into a Hundred equal Parts, in the same Manner as I observed to you of the *Base* or *Key-note* when it was a String:—But here the Beginning of the Division is from the End that enters the Pipe; therefore if you place it in the Tube to the Division 50, it will sound an Octave; but if you draw it back to 53, the Note will be a *Seventh* greater;—if you stop at 60, it will be a *Sixth* greater;—and after that at 40 $\frac{1}{2}$, the *Fifth* Note will be produced; again, by placing it to 75, you have the *Fourth* Note;—then again at 80, and you have the *Third* Note;—and, lastly, against 80 $\frac{1}{2}$, you have the *Second* Note, or that next to the *Key* or *Base* Note.—Thus, any Note of the Octave may be produced by the Pitch-pipe: And if the Notes in this first Octave be not high enough, you may go an Octave higher on the same Monochord, and so have a very great Extent of Notes in this Pipe.

Euphros. Then, I presume, the Reason why it is called a Pitch-pipe is because, by this Means, he that tunes the Harpsichord, or other Instrument, may be thereby able to pitch the Note, or Tune, to the proper Height above, or Distance from the Base Note; so that any of the seven Notes in the Octave may be ascertained by this Pipe; And thus all the Octaves, and consequently the whole Instrument, may be put into Tune, at any Time, by this mechanical Method.—I suppose, the *Rationale* of all Wind-instruments is nearly the same; as you have given me to understand; that Notes or Sound of this Kind depend upon, and result from the different Agitations and Vibrations of the included Air in the Pipes.

Cleon. What you observe is in general very just: But there is, at the same Time, great Art and Contrivance required in the Instrument-maker, with respect to the internal Structure and Bore of the Tube, or Pipe; and also the Form and Size of the Holes, or Ventages, by which those Sounds are modulated by the Fingers in Flutes, Hautboys, &c.—But the Capital, or most noble and magnificent of all the Instruments for Wind-music is the ORGAN, so called by Way of Pre-eminence; because the Word *Organ* signifies, in the original *Greek*, nothing more than an *Instrument*.—The Principal of Organ-music is in itself very simple and easy, as I have already shewn; nor is its Structure so very difficult, or complicated, as might be imagined from its pompous Appearance.

Euphros. The Aspect and Effect of the Organ are both in a superlative Degree: I am always ravished with its majestic Form, as well as with its divine and celestial Sounds. I think it is with the greatest Propriety consecrated to the Worship of the Deity; as it must be allowed greatly to assist all that Part of our Devotion which relates to sacred Music and Harmony, such as singing Anthems, Psalms of Praise, &c. and something of this Kind we find has always been in Use in Royal Chapels, and other chief Places of Worship.—But methinks, I should be glad to know something of the internal Structure of this Instrument, as I have never yet had an Opportunity of gratifying my Curiosity by an Inspection thereof.

Cleon.

Cleon. It will not be a great while before I shall take you with me to the Organ-builder's Room; where you will see and examine every Part which enters into its Structure; and, indeed, there is no Way for a Person to have a just Idea of the Structure of this Instrument, or any other Piece of Machinery, than by a real View of the several Parts that compose it, and the Manner in which they are put together by the Artificer: But, for the present, I shall give you a general Account of the several Parts of which it consists:——Under the Range of Pipes is a long Trunk, or hollow Box of Wood, made perfectly *Air-tight*, with which the Pipes communicate, and which, at the Time the Organ is playing, is constantly filled with condensed Air by Means of Bellows appropriated to that Use.——Externally, you observe a Set of Keys like those of a Harpsichord, each of which is adapted to its peculiar Pipe in the Organ:——These Keys, when put in Motion by the Organist, lift up little Springs, by which the condensed Air rushes out of the Magazine into the Pipes of the Organ.——The nether End of the Pipe is formed something like the Mouth piece of a Flute, by which such a particular Portion of Air is admitted as is sufficient to put the internal Air into those Tremours, and Vibrations, as are necessary to sound the intended Note, the other Part of the Air running Waste on the Out-side of the Tube:——And thus the several Pipes of the Organ, like the Strings of a Harpsichord, have their musical Effects produced, by one and the same Contrivance of a Set of Keys, which is a very lucky Circumstance, because the same Person can, by this Means, play either Instrument.

Euphros. From what you have said, I am able to form a tolerable Idea of the Nature of this Instrument, and the Manner in which this superior Kind of Music is effected:——But let me ask you one Question more, does not the Matter and Form of the Tubes contribute to meliorate the Notes, or Sounds, as well as the Sound-boards with which stringed Instruments are constructed?

Cleon. There is no doubt of it, my *Euphrosyne*; the more elastic the Tube is, the stronger and finer, and more

more sonorous and vivid will be the Sound, if I may so express myself: Of this you would soon be sensible, were the Air agitated in the same Manner by equal Pipes of Copper or Lead. The Strings of a Harpsichord would make but indifferent Music without the Sound-board, and elastic Air below, contributing, by their Elasticity, to heighten and perfect its various Notes.——In the Structure, therefore, of all Kinds of musical Instruments, we are not only to consider the essential Principle of each peculiar Species of Music, but, also, we must have a great regard to all concomitant Circumstances and Incidents which contribute to improve the same; for it is in MUSIC as in PAINTING, unless the Expressions of Nature are enlivened and embellished by the Graces borrowed from Art, the Performance will ever prove flat, cold, and unaffecting.——Thus I have, in a general Way, sketched out to you a comprehensive Plan of the Philosophy of musical Sounds, by which you will be enabled to read, with Improvement, the Works of those who have wrote largely on this Subject, and therefore shall conclude with a few Reflections not improper on this Occasion:——The first is, a Curiosity relative to musical Proportion, worth your Notice; by which there seems to be some Connection between the Sciences of MUSIC and OPTICS.—You remember all that I have said to you concerning the Reflection of Light from Speculums, and the Formation of Images thereby, from a given Distance and Situation of the respective Objects.

Euphros. What I can recollect of that Kind is principally this; that the solar Focus of a Speculum is at the Distance of $\frac{1}{4}$ Part of the Diameter of the Sphere, of which it is a Segment; and, farther, that when an Object is at any near, or definite Distance, the focal Distance, or Place of the Image, will exceed the Distance of the solar Focus, and so much the more as the Object is nearer to the Mirrour.

Cleon. Very well, my *Euphrosyne*: Then what I have now to advance, is this; that if a Right-line be conceived to be drawn, and a Mirrour be placed on any one Part of that Line, and an Object at a Distance in another Part of that Line, then the Place of the Mirrour,
and

and of its Center, and the Place of the Object and its Image, are four Points, which will ever divide that Line into **MUSICAL PROPORTION**: from whence we have this harmonical Analogy, as the Distance of the Object from the Center of the Mirrour is to its Distance from the Vertex thereof, so is the Distance of the Image from the said Center to its Distance from the Vertex: Or, in other Words, the Ratio of the Distances of the Object and its Image, from the Center and Vertex of the Speculum, will ever be the same.

Euphras. This, no doubt, is a very curious Proposition, both in Music and Optics; but I should have a much clearer Idea of it, if you could contrive to illustrate it by Example, or Experiment.

Cleon. That nothing may be wanting to your easy Conception of the Nature of so singular a Phenomenon, I shall illustrate it both by an Example and Experiment. For this Purpose I have provided a Speculum, which is the Segment of a Sphere just 10 Inches in Diameter, whose Center is therefore at the Distance of 5 Inches from the Vertex. Now, if I draw a Line just 10 Inches long, and place the Mirrour at one End of that Line, and any Object at the other End, then will the Center of the Mirrour fall on the middle Point of the said Line: therefore, if this Line be considered as a *Monochord*, it is evident, the Center of the Speculum falls upon that Point which is called the *Octave*, and the solar Focus is upon the Point at $2\frac{1}{4}$ Inches distant from the Vertex, which is that Note called the *Fourth*. Then the Object being placed at the End of the Monochord, its Distance from the Center to its Distance from the Vertex of the Mirrour will be in Proportion as 1 to 2: Consequently, the Octave, or Distance from 5 to 10, must be divided by the Image in the same Ratio, and therefore it will fall on the Point which is $6\frac{2}{3}$ Inches from the Beginning of the Monochord, and therefore will be formed on that distinguished Concord called the *Fifth*: So that, in this Example, the Place of the Object and its Image, the Place of the Speculum, its Center and solar Focus, divide the Monochord in all the capital Points of harmonical Proportion.

Euphros. But still, *Cleonicus*, though I do not dispute the Truth of all you say, it will be necessary to evince the same to me by an Experiment.

Cleon. That is the next Thing I propose, and which will not prove tedious or difficult in the least Degree; for having placed the Mirrour in its Frame, with the Center of the Pedestal at the End of the Divisions of the Line, or Monochord, I place a small lighted Wax-candle exactly on the Beginning of the said Line:—Then you see, by standing on this Spot, the Image of the Candle inverted, and the Point of its Flame exactly directed to the *fifth* Note, or Division of the Monochord.

Euphros. This, I observe, is really Fact, and fully satisfies me of the Truth of this most extraordinary Instance of Harmony in Optics.—Pray, is there any Case of a like Nature in any other Sciences?

Cleon. None, that I know of. You may have heard talk of the Music and Harmony of the Spheres, or Orbits and Motions of the heavenly Bodies; but there is no real musical Proportion in the Distances of their Orbits from the Sun, or their periodical Revolutions about it. —I have likewise, heretofore observed to you, that in the Refraction of Light by a Prism, the Spaces occupied by the different Colours in the variegated solar Image were nearly the same as the Parts, or Intervals between the musical Notes of an Octave: But this is a Matter, for aught we know, merely casual, as there is no geometrical or physical Demonstration of a musical *Ratio* in refracted Light in that Respect. —

Euphros. This is a curious Discovery indeed:—But what have you farther to observe, with regard to the Nature and Effects of Music?

Cleon. It may be very proper here to animadvert upon one Thing, *viz.* that when we know of any extraordinary Power, or Agent in Nature, we are generally apt to over rate it, or to ascribe more to its Virtue and Efficacy than was ever naturally due to it. To this injudicious Disposition in Mankind, we owe most of those ridiculous and extravagant Notions of Astrologers, or Auruspices, Soothsayers, and Conjurers of every Kind, which have formerly so much infatuated the Minds

of weak and wicked People, to the great Dishonour of an all-wise Governor of the World, and the Shame and Disgrace of human Nature.——This seems to have been the Fate even of Music itself: Its Powers are well known to affect the human Fabric, which is chiefly a Compages, or System of nervous Fibres and muscular Filaments, and thereby subject to all the Motions and Vibrations of Air; and, consequently, by those occasioned by musical Sounds in a very high Degree: and as the Passions of the Mind are affected, and variously excited by the Impulses of the nervous System, it is no Wonder that we oftentimes see the Power of Music affecting the Passions of Men, in respect to Joy, Mirth, Devotion, &c. in a very extraordinary Manner: Nor are we to wonder, if we find a Set of People ready to extend the Power of Music beyond the Force of Nature, and ascribing to it many Effects which it was never capable of producing.

Euphros. I suppose, by this Parody on the Weakness and Superstition of Mankind in regard to the Power of Music, you have some Object in View, like the famous Story of the BITE of the *Tarantula*, which is said to be curable by Music alone.

Cleon. That is the very Thing I hinted at:——It is amazing, to consider how such a Story gained so long and constant Credit with the most sensible Part of Mankind.——Dr. MEAD, very probably, might write from hear-say; but BAGLIVI, the famous Philosopher in *Italy*, who could not but have good Opportunities of informing himself with respect to this Insect (which is a Native of *Apulia*) has written a Treatise expressly on this Subject.——But notwithstanding these, and many other great Authorities, in favour of this Story, it is now deservedly looked upon as a mere Fiction, founded in Tradition and vulgar Error only:——As such, it has been treated by an *Italian* Physician of Eminence, in the *Philosophical Transactions*, and a great many Gentlemen of unquestionable Veracity, who resided at *Taranto* in *Naples* many Months, and during the Time in which the Bite of the *Tarantula* is said to be most pernicious, affirm, that there was not a Physician in the Country who believed there was ever such

such a Distemper, from such a Cause, and that Nobody ever remembers a single Instance of such a Thing; and, lastly, that there is no Spider to be found in that Country different from those which are common in most warm Climates.

Euphros. If this be the Case, how strangely have your great Philosophers, Physicians, and Divines been imposed upon, by so trifling a Thing as the fabulous Story of the *Tarantula*.——Does it not argue them to have been equally indolent and credulous?——Was it not in their Power, 100 Years ago, to have detected this Imposture?——Should not this prove a Lesson of Instruction to the *Virtuosi* of the next Generation, to be more circumspect in their Enquiries into the Powers of Nature, and not to be credulously assenting to every vulgar Report, to the no small Disgrace of their high Reputation?——Lastly, I think you have said enough for a *Memento* to the great Gentlemen of your own Sex, who are apt to value themselves so much on their superior Wisdom and Abilities, to be very moderate, for the Future, in their Reflections on the Weakness and Credulity of our's, since learned Men, as well as silly Women, it seems, can, for Centuries together, believe and acquiesce in such an old Woman's Story.——You forgive me, *Cleonicus*, these general Reflections, as you cannot but know they are highly due from our Sex, for the many genteel Strictures we daily receive from the *Literati* of your's.

Cleon. I think, my *Euphrosyne*, all that you have said is but too just a Retaliation, and you are certainly very right in so equitable a Vindication of the Honour and Character of the Ladies in general:——But, at present, we shall put an End to this Conversation, and, in our next, proceed to consider of those Organs with which Nature has furnished all Animals, and, in Particular, the human Species, both for forming and uttering of Sounds, as well as for perceiving and hearing the same.

DIALOGUE X.

On the ORGANS furnished by NATURE, for forming and variously modifying Animal NOTES, and Voice, or SPEECH in the human Species.

Euphrosyne.

I Am not very clear in the Subject of our present Conversation, *Cleonicus*: I remember you told me, when we last parted, that you should next discourse with me upon the natural Organs of Voice, or Speech, and, in general, how all animal Notes, or Sounds, are thereby formed and modulated. How am I to have a clear and distinct Idea of this natural Organization for forming and emitting animal Sounds?

Cleon. In this Affair, my *Euphrosyne*, I apprehend you will meet with very little Difficulty, since all the Parts of the general Organ for forming animal Sounds are such as you are well acquainted with, by daily Observation and Inspection.——Indeed, the Parts of this Organ are not solely appropriated to this Use; but, like many other Parts of the animal System, they are wisely designed, by the Author of Nature, to answer many Purposes, and to perform different Functions in the animal Oeconomy.——The parts of the vocal Organ are as follow, (1.) The *Lungs*. (2.) The *Trachea*, or Wind-pipe. (3.) The *Larynx*, which is the Upper-part of the Wind-pipe. (4.) The *Epiglottis*, which lies over the Aperture, or Mouth of the *Larynx*. (5.) The *Uvula*, which hangs from the Palate at the End of the Passage of the Nose. (6.) The *Tongue*. (7.) The *Teeth*. (8.) The *Lips*. These are all the principal Parts concerned in the Formation of animal Sounds.

Euphros. These seem to me to be hard anatomical Names, many of them; but, I suppose, the Things themselves will be easier to be understood: And, farther, as we observe in every different Species of Animals a peculiar Note, or Tone of Voice, or Sounds, which they naturally emit, therefore, in each of them, we are

to suppose there is a peculiar Disposition and Configuration of those Parts, to answer such different Modulations of Sounds.

Cleon. No doubt is to be made of this; for though the Parts may be essentially the same in all, yet their Shape, their Size, and their different Apparatus of Muscles, and many other Circumstances, may be infinitely varied in the numberless Species of Animals, and thereby an endless Variety of animal Sounds, Notes, or Voice is producible.——It is by this Means, that each Species has its peculiar Note.——Thus, the Dog *Barks*,——the Cat *Mews*,——the Cock *Crows*,——the Doves *Coo*,——the Sheep *Bleats*,——the Cow *Lowes*,——the Lion *Roars*;——but MAN alone SPEAKS.——It is observable, that the Fish alone, though they have many Parts of the aforesaid Organ, are yet entirely mute, or incapable of emitting any Note.

Euphros. You will next, *Cleonicus*, please to let me know the particular Office which each of these Parts perform in the Formation of animal Voice, or Sound.

Cleon. The LUNGS, which I have mentioned as the first and principal Part, are, in this Respect to the Animal, as the Bellows and Air-box is to an Organ; that is to say, by them the Air is inspired, or drawn into the Lungs in a sufficient Quantity by their Dilatation, as may suffice not only for Respiration, or Breathing; (which is their general Function) but also, by their Compression, to give a proper Impulse to the Air requisite for the intended Intensity of the Sound, or, in other Words, by a greater or less Compression of the Lungs we can express the Air through the Wind-pipe with different Degrees of Force, and thereby raise, or lower the Voice, as Occasion requires: In short, the Lungs are the general Magazine of Air for all the numerous Purposes in the animal Oeconomy, of which this of the Voice may be justly reckoned in the second Degree.

Euphros. Is this important Organ formed alike in all Animals, *Cleonicus*?

Cleon. I have observed some very considerable Difference in the Formation of this Part, in the Accounts

which Naturalists give us of it; but I shall refer you, for farther Satisfaction in this Point, to a most noble and valuable Work, *viz.* the anatomical Part of the *Memoires of the Royal Academy of Sciences at Paris*, from the Year 1666 to 1699, where you will find not only the best Iconisms of all the capital Beasts, Birds, Reptiles, Serpents, &c. that has been ever published, but a particular Account of all their Parts by a Dissection of each: And if you read it in *French*, it will at the same Time be an Improvement of your Knowledge in that Language.

Euphros. I thank you for your kind Direction and Advice: I shall take the first Opportunity of procuring such useful Treatises.—Pray, what is the next Part conducive to the Formation of Sounds?

Cleon. The second great Part in the Organ for animal Notes, or Sounds, is the *Trachea* or WIND-PIPE.—I have observed to you that, in all Wind-instruments, Pipes of one Form or other are necessary; but the Wind-pipe is most fitly compared to the Pipe of an Organ; and as it serves only for the Conveyance of the Air to the upper-part, or *Larynx*, it is of different Sizes, peculiarly adapted for expressing the different Sounds in various Species of Animals. A larger Account of this Part you will find in Dr. Grew's *Cosmologia Sacra*, or Mr. Derham's *Physico Theology*, both which Books are highly worthy of Perusal: But one Thing I cannot omit mentioning to you, as it is an Argument of the most obvious Design and wise Contrivance, *viz.* that as this Part lies immediately in the Fore-part of the Throat, and bears on its Hind-part upon the *Oesophagus*, or Gullet, by which our Food descends into the Stomach; and as it consists of Cartilaginous *Annuli*, or Rings, these, lest they should bear hard on the Gullet, are discontinued or broke off on the hinder Part, where it is altogether soft and membranous, as you may remember oftentimes to have seen, in this Part, in a Dish that frequently comes to your Table.

Euphros. I shall take more particular Notice of this Part the next Time I see it, as it is so highly deserving thereof.—Pray, what is the next Part concerned?

Cleon. The LARYNX, I mentioned to you as the third Part of the complex Mechanism for animal Voice:

This

This Part is no less useful, than wonderful in its particular Structure; it is placed on the upper Part of the Wind-pipe in the Throat, it may justly be considered as the most musical Part of the whole Organ, as it is particularly adapted to modulate or vary the Sound, or Voice, in every respect, that any particular Animal is capable of: For this Purpose, it consists of no less than five very curious cartilaginous Parts, all moved and actuated by particular Muscles appropriated to each. In the human Species, this Part has a peculiar Configuration, and is one of that infinite Number, in the human Fabric, that might justly excite the devout Exclamation of the Psalmist.*—In the beforementioned Authors you will find a great Variety in the Construction of this Part in different Species of Animals: In short, the *Larynx* answers to the Mechanism in the lower Part of an Organ-pipe, or Mouth-piece in Flutes, for modulating the Ingress and Egress of the Air in Speaking, Singing, &c.

Euphros. So far I have at least a general Idea of the organical Parts of Speech. Pray, what is the next which follows, contributing to this End?

Cleon. The next, or fourth Part, is the *EPIGLOTTIS*, so called, as being something in the Form of a little Tongue lying over the *Rimula*, or Mouth of the *Larynx*, always raised a little above it by an elastic Muscle, so that when the Aliments glide over it into the *Oesophagus*, it closes the Mouth of the *Larynx* so that nothing may get down the Wind pipe; but when they are past it, it rises again by its natural Resort. This answers to that particular moveable Piece in the *German Flute*, *Organ-pipes*, &c. by which the *Rimula*, or Passage for the Air, is made greater or less for the proper Modulation of the intended Note, or Tone of the Sound: But this Part in the animal Structure as much exceeds the other, as the Voice, or Notes of Animals is an Effect superior to the Notes of a common Pipe: The manifest Design and Contrivance of this Part being beyond Admiration itself.

Euphros. The Part which you have now described, I apprehend, is concerned in the original Production and

Modification of the Voice ; but the other Parts which follow, I presume, are to render the Voice or Speech more articulate and distinct ?

Cleon. That is their particular Office ; for without them the Wind-pipe would be no more than a common Flute, for barely modulating Notes or Sound : But, by the Assistance of the other Parts of this Organ, those Notes or Sounds may be said to be properly configured, or formed into all that infinite Variety of Sounds which are necessary to constitute Voice, or Speech : Amongst these, the first is the *Uvula*, which I mentioned to you as the fifth Part concerned ; this hangs from the Palate, in the upper and hinder Part of the Mouth, before the Passage into the Nose : It has two Uses, one is to prevent any Thing regurgitating into the Nose in Deglutition, and the other is, by its various Muscles and Motion, to contribute to the particular or special Modification and Articulation of Sounds, at its first Entrance into the Mouth : Since we find this is very often experienced when, by a Disorder in this Part, it is necessary to extract it ; that the Voice without it is very obtuse and indistinct, and the Person speaks, as we say, *through the Nose*. — By looking into any Person's Mouth, you will readily discern this Part pendant from the Palate over the Throat.

Euphros. Well ; but notwithstanding this, I presume the *Tongue* is the principal Instrument for rendering the Voice articulate ?

Cleon. Undoubtedly it is ; the *TONGUE* is the sixth Part which I mentioned in the Structure of this general Organ, and is not only the Principal but the most absolutely necessary Part, for the general Articulation of Sounds, especially for verbal Notes or Speech, which are wholly indistinct and unintelligible where this Part is unhappily wanting, as you too often find by Experience ; there is so much natural Art in the Use of the Tongue in this Respect, that the Tongue itself is not capable of expressing ; it is an Instance of that divine Energy which we can only admire, but never fully understand : It is the grand Instrument of Speech to the human Species, and serves to modulate the Expressions of the Passions, by proper Notes of Sound in all others.

Euphros. As you are upon the Subject of the Tongue, *Cleonicus*, you will give me Leave to ask, what farther Purposes

Purposes it serves besides that of Speech? It seems to me to be the *Seat*, or the Organ of *Taste*. I should be glad to have your Sentiments on this Subject.

Cleon. You may command me in any such Respects as freely as you please:—And, to tell you the plain Truth, it is so eminently distinguished as the Organ of TASTE, that it is, for ought I know, its primary Function or Faculty; for it is well known to Anatomists, that there is a Pair of Nerves which proceed from the Brain to the Root of the Tongue, and there disperse in a wonderful Manner through all its Parts; and terminating in little capillary Eminences on the upper Side of the Tongue, occasions that small Degree of Asperity, or Roughness, which we there perceive: These are called the *Gustatory NERVES*, because being affected by the *saporific* Particles of the Aliment, or any other Body to which the Tongue is applied, they render us immediately sensible of that Quality which is call, their *Sapor*, *Relish*, or TASTE; and this is the Substance of the general Doctrine of this SENSATION.

Euphros. It is sufficient to give me a general Idea of Taste, and that is all I can expect at this Time. You will now proceed to the other Parts of this general Organ of Speech.

Cleon. The TEETH and PALATE are the next Instruments of Speech; you will easily find how considerable their Office is in this Respect, if you only attend to the different Notes or Tones of the Sound expressed with the Teeth, shut and open; or by pronouncing the different Letters of the Alphabet without applying the Tongue to the Teeth and Palate; also, it is a very common Observation, that the Voice of Persons who have lost any of their Fore-teeth is very different from what it was before, and considerably less articulate. It would be endless to be particular in shewing how far the Teeth are concerned in rendering the human Voice perfect, though, in regard to other Animals, they are of little Importance in this respect.

Euphros. I can easily experiment the Truth of what you have now said, and am fully satisfied of it from common Observation.—I think you mentioned the *Mouth* as the last Part of this Organ of animal Voice?

Cleon. The MOUTH and Lips are the most essential of all the Parts to modulate and articulate the Sounds, especially

especially in our own Species; all the Variations of Sound, from the lowest Whisper to the loudest Vociferation, depend on the different Aperture and Configuration of the Lips. This likewise is evident in the Whistling and Singing of most Kind of Birds, their warbling and tuneful Notes being in a great Measure formed and modulated thereby.——And thus, I think, I have enumerated to you all the different and essential Parts concerned in composing this grand Contrivance, or Organization for animal Sounds; though there is one more most eminent Part, in the animal Fabric, that cannot be excluded from having some Share in the Production, or, at least, in the Perfection of this great Faculty.

Euphras. By your Manner of Expression, *Cleonicus*, I guess you mean the Nose; this, we know, is the Seat of the Sensation of SMELLING, and I am fully satisfied, at the same Time, that a free Passage through the Nostrils does greatly contribute to a distinct Expression of the Voice, as we easily find by holding the Nose when we speak.

Cleon. Your Observation is very just; the Nostrils undoubtedly contribute to a free and clear Expression and Formation of animal Sounds, or Voice; but I did not chuse to mention this before as one of the Parts of the Organ of Speech, as it is in itself a capital Organ of Sensation; I mean, that of SMELLING, as you just now observed; for the Anatomists shew us a Pair of Nerves which, in a most obvious and curious Manner, are detached from the Brain to the Origin of the Nose, and there, in a wonderful Divarication, are spread over all the Surface of the Nostrils, whose fine capillary Extremities, being affected by those particular Particles in Bodies in which their ODOURS consist, prove the Means of exciting in our Minds the Notions, or Ideas of that odorific SENSATION, or Faculty, we call the SMELL. I shall, one Day or other, take an Opportunity of dissecting the Bill of a *Mallard*, or *Drake*, where you will be apprized of the most exquisite Scene of Wisdom and Design in the Structure of this Organ in that and other such Species of Animals, who are obliged to smell out their Food, or proper Aliment, when it lies concealed from the Sight. I think, for my own Part, the curious

Dis-

1. DISPOSITION OF THE YEAR.



A DISSECTION of the EAR.

Plate LII.

Fig: 1.



Fig: 4.



Fig: 5.

B



Fig: 3.



Fig: 6.

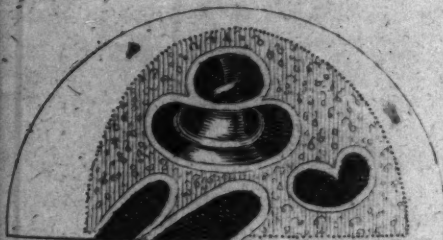


Fig: 7.



Fig: 6.

Disposition of the *olfactory Nerves*, and their amazing Ramification through all the broad Part of the Beak of this Bird, is one of the most delightful and astonishing Sights I ever beheld.——I make no Doubt but the Case would appear the same, or, perhaps, much more exquisite in the nervous Structure of this Organ in the Nose of Dogs, whose Powers of Sensation in this Kind are well known by Instances which exceed all human Conception and Description, and, I take it, that excepting the *Sight* alone, the *Organ of Smelling* is the most exquisite in the animal Oeconomy.

DIALOGUE XI.

*Of the FACULTY, or SENSATION of HEARING;
with a DESCRIPTION of the particular Parts
concerned in the Organization of the EAR.*

Euphrosyne.

AS you have obliged me with a general Account of the philosophical Principles of Sounds, both animate and inanimate, which has not a little contributed to the Expansion of my Mind, and Improvement of my Understanding; yet I remember you told me, I should never be perfect in this Part of the Science, till the very Organ itself, by which those Sounds are rendered perceptible to us, be fully considered and understood; which, I apprehend, will be very difficult for any one to comprehend without having the several Parts of this Organ exposed to View, by an actual Dissection of the EAR: This, when we parted last, you was so kind as to tell me you would provide for the Subject of my next Entertainment.

Cleon. This I have accordingly done, having obtained the Favour of a Preparation of all the Parts of the *human EAR*, curiously preserved, from an ingenious Acquaintance, whose Character, as a Surgeon and Anatomist, is not the least eminent in his Profession.—You see them here nicely disposed, upon Cotton, in the little Compartments in this Box.

Euphros.

Euphros. It is, no doubt, a fine Curiosity of this Kind; but, by a general View of the several Parts thus dislocated and detached from each other, I cannot form any consistent Idea of the Form and Structure of this Organ, as it naturally exists in the Head.

Cleon. But that you will more readily do by another anatomical Preparation of the Ear, in which all the Parts have their natural Position, and, by a particular Contrivance, are easily exhibited to the View:——See, in this other Box, the ORGAN of the EAR entire.

Euphros. This is, indeed, a most extraordinary and noble Sight; but even in this Case I see a miscellaneous System of I know not what, till you shall please to describe the several Parts of this complex Organ, and give me a particular Account of the Uses of each, in producing this wonderful Sensation.

Cleon. That is more immediately the Business and Purpose of our Meeting at this Time. I well know how difficult it is for any Person to have an Idea of the Nature and Manner of this perceptive Faculty, without an actual View of the Organ itself, and its several Parts distinctly. The other Organs of Sensation, as you have seen, are not so difficult of Access or Comprehension, and therefore I have been the more solicitous to make this of HEARING in particular, equally understood by you.

Euphros. I am vastly obliged to you, for your Care and Solitude to inform and enrich my Mind with every valuable Acquisition of Knowledge:——You will please then to begin, and proceed in your Description of the several Parts of this curious Organ.

Cleon. I will:——But I must first of all observe to you, that the Parts which you here see in Boxes are the *internal Parts* of the Ear only; but we must begin our Description with the external, and intermediate Parts, to render the whole complete. Therefore,

First, the external Part, which we vulgarly call the Ear, is of a curious Form for the better Collection of Sounds, and is placed on each Side of the Head of Animals, (like two natural Hearing-trumpets,) to collect the Sound which comes from every Part; and the Duplicature of this Organ is a benign Provision for any Accident by which we may be deprived of one, as we have remarked before in the Case of Vision.

Secondly, the *Meatus Auditorius*, or Passage to the internal Ear, receives the Sound from the external Part, where it is augmented as in the Tube of a Trumpet, and, as it were, condensed upon.

Thirdly, the *Membrana Tympani*; or Drum of the Ear, which is this curious membranous Part which you see here extended quite across the Ear, and being almost of a circular Form, represents the Parchment Membrane, or Head of a Drum: In the *Sinus*, where this Membrane is placed, there are some Parts in the Nature of little Springs, (as you may observe in this Preparation,) by which this Membrane is tended, or relaxed, in order that the Vibrations of the internal Air may be thereby rendered more or less intense, as the Occasions of this Sensation may require; for, if the external Sound be too great, this Membrane may be relaxed to moderate it; or, if too low, it may be strained higher to augment or heighten it; all which is analogous to the Mechanism I have formerly observed to you in the Pupil of the Eye, with regard to too intense or too weak a Light.

Euphros. A most wise and very wonderful Contrivance, indeed?—Those little Parts which appear like Bones on the Inside of that Membrane, I presume are the little Springs that you speak of.

Cleon. They are: The first of these consists of two little Bones, called the *Malleus* and *Incus*, or the Hammer and Anvil: These contribute to extend and relax the Membrane principally.——The second Spring consists of the same *Incus*, and another little Bone called the *Stapes* or Stirrup, joined together by a third little Bone called the *Os Orbiculare*, and the Basis or Foot of the Stirrup is the Passage, or makes the Entry into the second *Sinus* or Cavity of the Ear.

Euphros. Pray, is this Membrane so perfectly extended over the Passage of the Ear as entirely to cut off all Communication between the internal and external Air?

Cleon. It is but very lately that it has been discovered to have a small Perforation on one Side, which opens into a Canal called *Eustachius's* Tube, from the Author's Name who first observed it: This Tube opens itself toward that Part of the Mouth which communicates with the Nose; and hence it is that some People, by
shutting

shutting their Mouth and holding their Nose, can force the Smoke of Tobacco in a visible Manner through their Ears, through this small Chink first detected by *Rivinus*.

Euphros. By such an odd Kind of Experiment a Communication between the internal and external Ear is put beyond all Dispute:——But, pray, *Cleonicus*, is not such a Hole necessary in the Nature of an Organ of Sound? Because I have always observed it in all Instruments, as the *Æolian* Harp, Violin, &c. where a Body of Air is contained under a Sound-board beneath the Strings.

Cleon. There is no Doubt but that every Part in the Ear is perfectly adapted to a just Modulation of harmonious Sounds, and to meliorate their Tones; and that this Perforation in particular may not a little contribute thereto, as you well observed, we find it does in most Wind-instruments.

Euphros. Pray, what are those Parts which I observe within the Ear, in the curious Form of a Snail-shell?

Cleon. The Passage or Part just behind the Drum of the Ear is called the *Vestibulum*, being, as it were, the Antichamber or Entrance to two other Cavities or Apartments in the Ear: The first of these Cavities is called the *Labyrinth*, consisting of these Semi-circular Canals; and the second is called *Cochlea*, from its Resemblance of a Snail-shell, as you may see by their Appearance in these Preparations.

Euphros. They seem to be very curious Parts, indeed; and what you call the Labyrinth appears to me to have something of the Mechanism of a Winding-horn, or Hearing-trumpet.

Cleon. Not only the Form, but its Use is undoubtedly of the same kind, *viz.* to increase the Agitations of the internal Air, or to make them more sensibly affect the Fibres of the auditory Nerve, to which a *Vestibulum*, or Passage with which they all communicate, may not a little contribute; as also, those little Membranes which you here see extended in the Entrance into each of them. This *Labyrinth* of Winding-tubes is supposed to be the general Organ of Hearing:——But that which is destined for the more delicate and refined Uses of Hearing, such as the forming and modulating musical or harmonical Sounds, seems

seems to be this other second Cavity of the *Cochlea*, in whose curious and most perfect Mechanism you observe two spiral Windings or Canals, separated from one another by a thin nervous Membrane, supported through its Length by the Projection of bony *Laminæ*, as you may see in this *Cochlea* by a proper Section through it.

Euphros. I observe it with a great deal of Pleasure; and, as this Winding-passage grows narrower towards the Summit, I apprehend the Fibres of the auditory Nerve, displayed through the same, may be supposed to have some Resemblance to the System of Strings in a Harpsichord, and that in this Part we may expect to find the true Seat or Cause of Concords and Discords, or of the Harmony and Dissonance of Sounds.

Cleon. Your Conjectures perfectly coincide with those of the best and most experienced Naturalists, who have always conceived this to be the Case, but in an infinitely superior Degree to any Thing that we can find in the human Construction of a musical Instrument; for in such an infinite Variety, in the Lengths of nervous Chords, it will always happen that some or other of them will be in Unison, or some other Concord with the Vibrations of the Air impressed; and other Nerves in Discord with other Vibrations of the said Air.—This, at least, is some Way of accounting for the mechanical Production of Sounds, and musical Notes in this Organ: But you are not to expect that we can, at all Times, declare the full Intent and Purpose of every Part which we observe in the Contrivance of this, or any other Organ of Sensation.

Euphros. It is to be esteemed a great Condescension, that we are admitted to so near and so affecting a View of Nature and her great Operations, as to give us those extended and exalted Notions and Ideas which we thereby acquire of the divine Author himself. How little can they be properly said to know of the Deity, who are ignorant of the Works of his Hands? For my Part, I shall ever think it my greatest Felicity to have been thus conducted, by you, through a Series of these most useful Speculations, on the most interesting Subjects of this Kind, and which will ever endear you to me under all the Relation of a *Friend*, a *Brother*, and a *Tutor*; and which is all the Acknowledgment I can, at present, make for your assiduous and indefatigable Care

to enrich my Mind, and to improve it with the most invaluable Principles and Parts of human Knowledge.

A Description of the several Parts of the EAR.

Fig. I. A B, the external Ear. C D, the internal Part, or Organ of the Ear, consisting of the *Drum*, the *Labyrinth* and *Cochlea*. E, *Eustachius's Tube*.

Fig. II. Shews the *Tympanum*, or *Drum* of the Ear, with its proper Apparatus of Bones in their natural Situation, viz. A, the *Tympanum*; B, the *Malleus*; C, the *Incus*, or *Anvil*; D, the *Stapes*, or *Stirrup*.

Fig. III. Shews those Bones separately, viz. B, the *Malleus*; C, the *Incus*; D, the *Forepart*; and E, the hind Part of the *Stapes*.

Fig. IV. Is a View of the *Labyrinth* and *Cochlea* connected. A, the Superior; B, the Middlemost; and, C, the inferior *Semicircular Canals* of the *Labyrinth*.

D E, the *Vestibulum* of the *Labyrinth*; F G, the *Cochlea* with one of its *Spirals* opening into the *Vestibulum* D E, and the other into the *Drum* at H.

Fig. V. Another View of the *Labyrinth* and *Cochlea*, shewing those Bones in the *Tympanum* which open into them, viz. the Holes called,

1. The *Fenestra Rotunda*, which opens into the *Cochlea*.
2. The *Fenestra Ovalis*, which opens into the *Vestibulum*.
3. The *Exit*, or opening of another Canal.
4. The *Spiral* of the *Cochlea*, opening into the *Vestibulum*.
5. The other *Spiral* opening into the *Tympanum*.

Fig. 6. A Section of the *Cochlea*, with the membranous Partition taken away, shewing the Blood-vessels ramified through its two spiral Cavities, A and B.

Fig. VII. Another Section of the *Cochlea*, shewing the Holes for the Passage of the auditory Nerve to the *Cochlea*.

DIALOGUE XII.

*Of the General SENSE of FEELING.**Cleonicus.*

IN some of our last Conversations, my *Euphrosyne*, we have touched upon the *Organization*, or particular Conformation of the Parts, which Nature has appointed for the Production of four Senses out of the five, *viz.* those of VISION, HEARING, SMELLING, and TASTING, which are called *particular Sensations*; I shall therefore now proceed to propose to your Reflection the *Rationale* of the remaining fifth, which is the *General SENSATION* of FEELING.

Euphros. You will make me very happy, my dear *Cleonicus*, to bring me acquainted with a Subject of so great and important a Nature—I remember you constantly observed to me, that each Sensation was produced by its peculiar Organ, or *Pair of NERVES*—I could readily conceive how this might be done for a special Part—But how will it be possible for one to get an Idea of so universal a Sensation as we find in every Part of the Body?

Cleon. This may be done with Ease, dear Sister, by only considering that as a single or specific Sensation is owing to a single Part of the *Nervose System*, peculiarly qualified to excite it, so the *General Sensation* is owing to a general Cause of the same kind, that is an universal System of Nerves disposed through the whole, and every individual Part of the Animal Body.

Euphros. But this requires a prodigious Stretch of Thought, *Cleonicus*, for me even so much as to form the least Idea of such an amazing Effect! For since every Point in the Body is sensible of a *Touch* from any Object, it should seem to me that the whole Animal consisted of nothing else but Nerves; how account you for this *Cleonicus*?

Cleon. You must not be too sanguine in your Expectations of my accounting for the unaccountable *Phænomena* of Nature; but this you may be assured of, that besides Nerves, there are many different Parts

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and

and Vessels in the Substance and Constitution of the Body of an Animal, as *Arteries, Veins, Membranes, Muscles, Viscera*, &c. of many kinds; as also *BONES* which are the *Frame-Work*, and Support of the whole.

Euphros. Well, but *Cleonicus*, I suppose you will allow all these constituent Parts of the Body to be endued with exquisite Sensation, which must be occasioned by Nerves in each of them also, (if Nerves be the immediate Organs of Sensation, as you say,) then I should think it would follow, that every Part of an Animal Body, and consequently the Whole, must consist of a *mere Mass of Nerves*, or *nervous Substance* only. If you can think otherwise, *Cleonicus*, you can instruct me to do so too.

Cleon. To tell you the plain Truth, Sister, I must confess I am much at a loss how and what to think about this, and all such natural Mysteries. We see the Operations of Nature in her larger Traits; we are permitted to see the *Origin*, but not the *finishing Strokes*; we observe the first of the *Nerves, Arteries, Veins*, and most of their stupendous Divarications and Dispersion through the various Parts of the Body; but this no longer than they are visible to the naked or microscopic Eye; after they escape the Sight, all is involved in Darkness and Inscrutable Mystery.

Euphros. I beg you, *Cleonicus*, not to think I want to know more than Nature has deigned to reveal. I have learned enough from your various Elucidations, to be convinced, that human Knowledge is greatly circumscribed; and that it would be almost a Profanation to be curiously prying into many of those secret and sacred Phenomena, which we may revere and admire, but want the Faculty or Power to comprehend.

Cleon. Upon my Word, *Euphrosyne*, I wonder Men don't allow Women to preach to them, as well as to reign over them. There are few of our Sex that need be shamed of the learned Documents they might receive from the almost *Ciceronian Eloquence*, and *Newtonian Matheſes*, of some of your's—But *Petticoat-Government*—

Euphros. Not so fast, *Cleonicus*, in your odd Sort of Raillery, you praise and disparage the Ladies both in one Breath—

Cleon. That's your mistake, my *Euphrosyne*; I praise the Ladies, 'tis true; but the Disparagement falls on the men who act an absurd and ignoble Part.

Euphros. But pray *Cleonicus*, what has all this to do about the *General Sense of Feeling*——I think we begin to loose Sight of the Subject—

Cleon. Why indeed, my *Euphrosyne*, I have said as yet but very little on the Subject; and, what is worse, have very little more to say about it, but what is quite precarious——Thus we are told, the Nerves convey *Animal Spirits* to all Parts of the Body for producing Life and Sensation; also—

Euphros. But not too many things at once, *Cleonicus*,——let me first know what you call *Animal Spirits*?

Cleon. That's more than I can do, Sister; I am not convinced by any Argument or Experiment whether any thing under that Appellation has really any Existence; nor do we find it possible by the Microscope to discover whether the Nerves are fine capillary Tubes, or solid Filaments, or Threads; it is certain only that they are the most *immediate Cause* of Sensation in every respect; but how and in what manner they are so, is not (perhaps,) in Man to say.

Euphros. But how are you sure, *Cleonicus*, that the Nerves are really the *Cause of Sensation*?

Cleon. By many evident Arguments; as first, wherever a peculiar Sensation is intended, there you always find an Organ animated by a special Pair of Nerves to produce it, as we have seen in the *Eye*, the *Ear*, *Nose*, *Tongue*, &c. Secondly, it is found by Experience, that when a Nerve is cut asunder, wounded, or tied with a String, the Part to which it is appropriated is thereby rendered useless, paralytic, and without Feeling. Thirdly, they are evidently a most important Part, as the whole System of Blood-vessels, *viz.* Arteries and Veins is constantly accompanied by a similar System of Nerves in all their Ramifications and Distributions through the Body—Fourthly, if Sensation be not the Effect of Nerves, we know not what is the Cause of it at all.—Fifthly, it is the universal Opinion of the wisest and most experienced Part of Mankind, that the Nerves are the natural *Means of Sensation*.

Euphros. You need not alledge any more Reasons, *Cleonicus*, as whatever is Conviction to the Learned, ought to be so to me, and every one else.—— Let me ask you one Question more, and I have done; is not the *Brain the Origin of the Nerves?*

Cleon. It is, my *Euphrosyne*, for the four Pair which are destined for the particular Senses seated in the Head; but there is a Sort of Continuation of the Substance of the Brain through all the *Vertebrae*, (which make the *Back-Bone*,) and is vulgarly called the *Spinal Marrow* from whence proceed many different Pair of Nerves (all the way down.) and are detached to all Parts of the Body for general Sensation.—— They are supposed (by our greatest *Anatomists*) to terminate in the Surface of the Skin, in those little Heads or Protuberances they call *Papillae pyramidales*, and are covered by the Cuticle, or Scarf-skin.—— I have previously prepared a View of them in the Microscope for your better Information.—— There, view them my *Euphrosyne*.

Euphros. I do; I see what you call *Papillae* very plainly; little rising Tubercles, at a sensible Distance from each other, and placed in Rows, as it were, along the Skin, which seems to be furrowed or channelled for the Purpose.—— They are somewhat opakish at Bottom, but at the Top they are all transparent, and in some there is almost the Appearance of a Pore or Perforation.

Cleon. I see you have surveyed them very critically, *Euphrosyne*; but you observe that these *Papillae* have large Spaces between them, for the most Part; and, therefore, if the Nerves terminated in them only, there would be a considerable Part of the Skin without Sensation, because without Nerves; but this is not consistent with Experience, since you cannot apply the Point of the finest Needle you use, with the least Degree of Pressure, but you feel it, and with a painful Sensation.

Euphros. I have very often a Proof of that, *Cleonicus*; and hence I suppose it may be presumed that most of the Sensations of Feeling are of the pleasurable or painful Sort.

Cleon. They are, my *Euphrosyne*, for if Objects touch us in one Manner they give us *Pleasure*; if in a different one, they give us *Pain*: But what those peculiar Modes

Modes of the Touch may be, we are again at a Loss to conjecture.—All that we know, is, that all pleasurable Sensations arise from the Touch, but some of the painful arise from other Causes, as *Hunger, Thirst*, and other Appetites, of which we are not able to form Ideas.

Euphros. I fear by this Time I have pretty well tired you, *Cleonicus*, or else my Curiosity would prompt me to ask you one Question more, *viz whether it be possible for a blind Person to distinguish Colours by the Touch?*

Cleon. There are many Instances of this Sort in the Affirmative upon Record; and these have been sanctioned by the Credulity of such great Names as *Boyle, Derham, &c.*; but the Assertion of *one Dr. Saunderson* is of more Weight with me, who always declared he never could do it, and that it was *pretending to Impossibilities*.

Euphros. I have heard so much of that blind Gentleman, that I think if he could not, no other ought to be credited; and indeed this one Anecdote furnishes a Proof that Credulity will sometimes find a Place in the highest Characters for Reputation, though it is usually reckoned the most degrading Attribute of the lowest.—I thought to have troubled you no farther; but I remember, *Cleonicus*, I once heard of a Person that *could see every thing but Colours*; and that of those he never had the least Idea; do you think this credible?

Cleon. I happened, luckily, to be acquainted with a Gentleman who knows that very Person you speak of.—He is a Haberdasher by Trade, which is somewhat extraordinary.—When his Customers ask for this or that coloured Ribbon, he takes out a whole Drawer of all Colours, and sets before them, to chuse which they please.—I know also another Gentleman, who assures me he had a Servant that could see or distinguish no Colour but *Green*, and knew nothing of any other.—But, see, here is a Summons to Dinner, my *Euphrosyne*, so we must adjourn, for the present, any farther Speculations on these Subjects.

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The ninety-third is the fact that the...
The ninety-fourth is the fact that the...
The ninety-fifth is the fact that the...
The ninety-sixth is the fact that the...
The ninety-seventh is the fact that the...
The ninety-eighth is the fact that the...
The ninety-ninth is the fact that the...
The hundredth is the fact that the...

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